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U S ARMY NATICK LABORATORIES

TECHNICAL REPORT

ES-12

CANAL ZONE ENVIRONMENT - PACIFIC SECTOR

EARTH SCIENCES DIVISION

AUGUST 1964

NATICK, MASSACHUSETTS

AD- Div. 2:3 Accession No. UNCLASSIFIED

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2. Climatic factors
3. Geography
4. Canal Zone
5. Testing areas
6. Terrain
7. Vegetation
8. Panama

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II. Title
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EARTH SCIENCES DIVISION

Technical Report
ES-12

6

CANAL ZONE ENVIRONMENT - PACIFIC SECTOR

fdc

10 by Robert L. Anstey.
~~Geographer~~

Project Reference:
1K025001A129

August 1964

FOREWORD

This report is one of a series describing environmental conditions at sites in parts of the world that may be used for testing Army clothing and equipment. The report deals with the wet-and-dry tropical environment in the Pacific Sector of the Canal Zone in Panama, with particular emphasis on possible testing areas. The detailed treatment gives required facts to product technologists and design engineers on environmental conditions that may be encountered in field testing. An attempt has been made to present as much of the information as possible in graphic or tabular form. Textual material supplements the maps and graphs and describes certain elements of the environment that do not lend themselves to graphic presentation. The environmental conditions described herein are similar, if not wholly analogous, to those of many other wet-and-dry tropical areas, such as Viet Nam, Thailand, Ghana, Tanganyika, and southern Congo.

PEVERIL MEIGS, Ph.D.
Chief
Earth Sciences Division

Approved:

DALE H. SIELING, Ph.D.
Scientific Director

CLIFFORD T. RIORDAN
Colonel, QMC
Commanding

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ABSTRACT

The Pacific Sector, Canal Zone, contains numerous areas favorable for testing or training in tropical environments under the political jurisdiction of the United States. The climate of this area is tropical wet-and-dry, typical of savanna areas. Seasonal differences in climate are significant in testing program results. The dry season is not representative of wet-tropical conditions, and testing conducted in this sector during this time would not yield the same results as that conducted in a true wet-tropical environment. Vegetation consists primarily of tropical deciduous forests on the uplands and marsh plants or swamp on the lowlands. Dense vegetation tends to grow in forest clearings. Inland the landscape consists of numerous low rounded hills; coastal benches and terraces are fringed by wide mud flats exposed only at low tide. Representative savanna areas may be found in the Rio Hato Military Reservation, 64 miles west of the Canal Zone in the Republic of Panama.

CANAL ZONE ENVIRONMENT - PACIFIC SECTOR

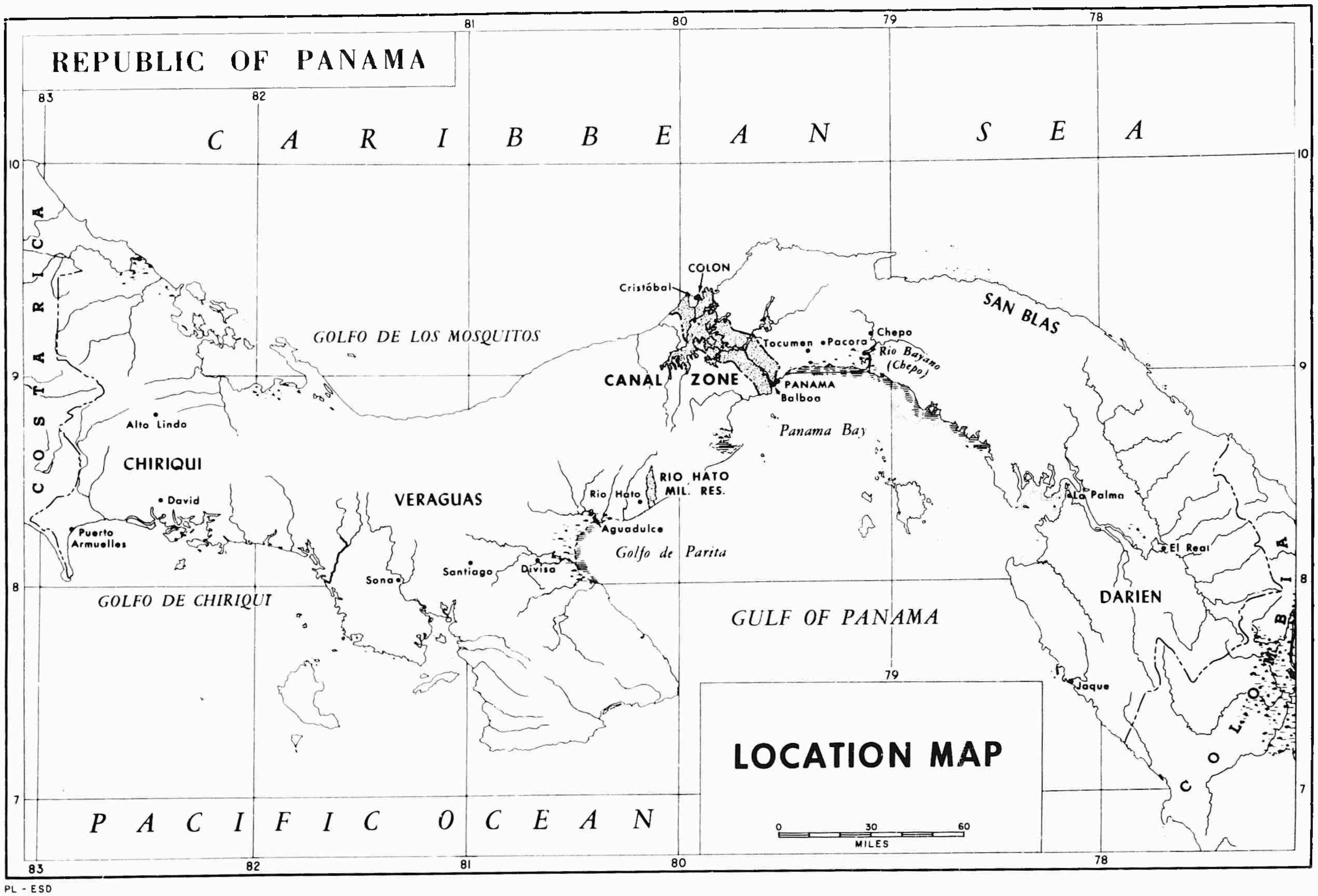
1. Introduction

a. Purpose and Scope

The purpose of this report is to describe the environment in areas desirable for Army testing or training activities in the Canal Zone and in suitable nearby areas in the Republic of Panama. Testing or training activities may be located in a grassland, mangrove, or tropical deciduous forest, depending on the specific requirements for experience, study or evaluation. In most instances, these requirements need not be relaxed in the Canal Zone in favor of more accessible areas. This report contains information (see Fig. 3) on the size and location of specific vegetative formations. This information is useful in the proper identification of testing or training activities. For example, there are no rain forests in the Pacific Sector. Tests in tropical deciduous forests during the rainy season may be conducted under conditions similar to those in rain forests, but they may not be fully analogous. Environmental conditions in tropical deciduous forests during the dry season are not analogous to those of rain forests. Most of the land near the coast in the Pacific Sector of the Canal Zone (Fig. 1) is included within either a military reservation or a housing area for Panama Canal Company employees. Inland and immediately adjacent to these establishments are numerous unused areas where approved testing or training activities could be conducted. The Venado Beach Range and the Empire Range (see Fig. 2), however, should be used only with special permission from G-3, USARSO. Land licenses are issued by the USARSO Engineer for all activities requiring land use. New testing or training activities requiring authorization for land allocation within the Canal Zone should use this channel for requesting a land license.

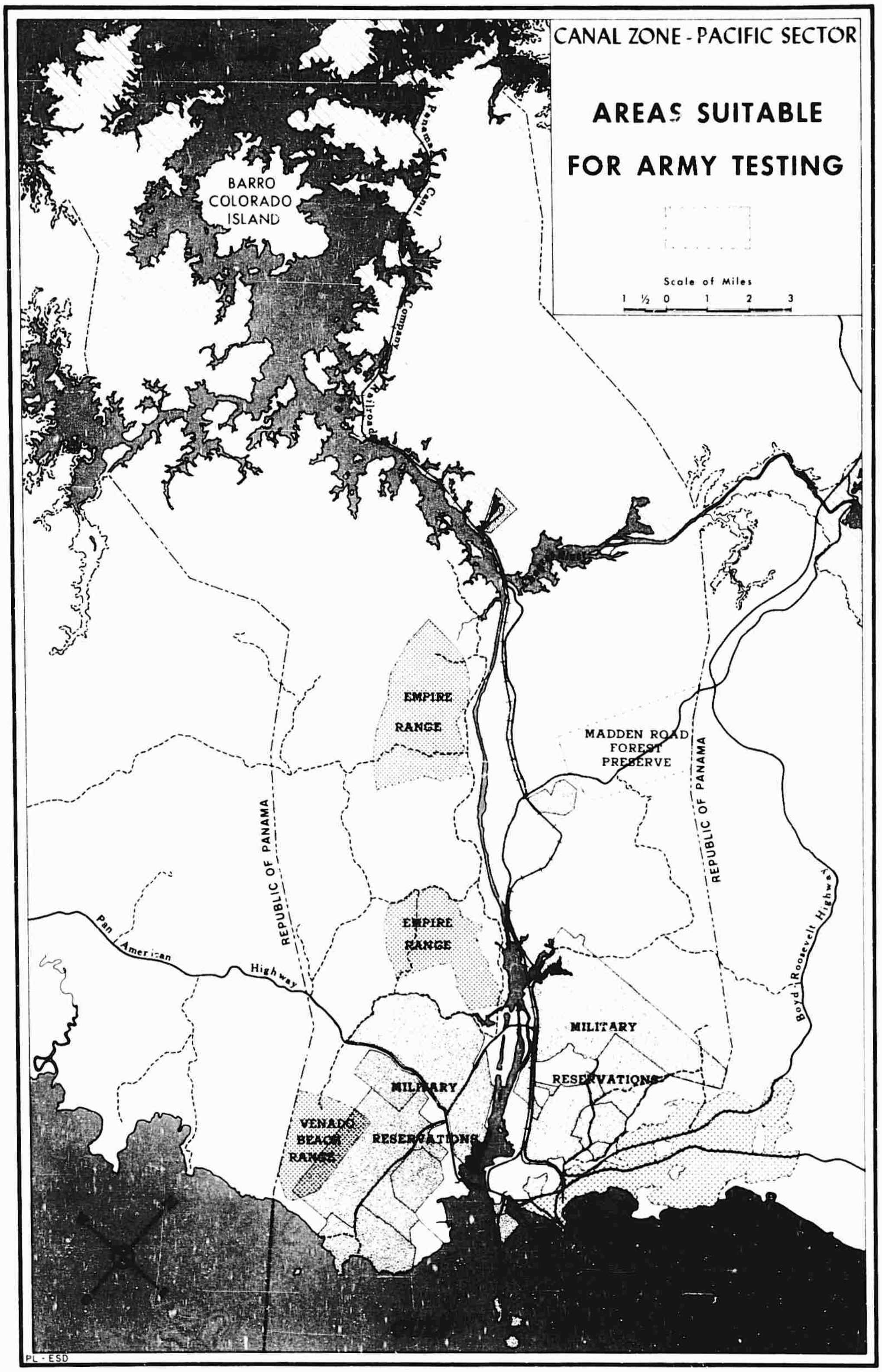
b. Military Installations

Army installations in the Pacific Sector of the Zone include Cerro Pelado, Cerro Tigre, Cocoli, Corozal, Curundu, Fort Amador, Fort Clayton, Fort Grant, Fort Kobbe, Madden Wye, and Quarry Heights. Naval installations include Arraijan Tank Farm, Farfan Radio, Naval Ammunition Depot, Rodman Naval Station, Summit Radio Station, and Headquarters, USNAVSO. USAFSO activities are conducted at Albrook Air Force Base and Howard Air Force Base. Housing areas in the Pacific Sector include Ancon, Balboa, Balboa Heights, Curundu Heights, Diablo Heights, Gamboa, La Boca, Lacona, Los Rios, Paraiso, and Pedro Miguel. These areas are used mostly by Panama Canal Company employees. The Panama Canal Company operates the Palo Seco Leper Colony. The Federal Aviation Agency offices are located at Cardenas Village. The administrative offices of the Panama Canal Company are located in Balboa Heights. Headquarters CINCUSSOUTH is now located at Quarry Heights; USARSO Headquarters is at Fort Amador (Figs. 1 and 4).



REPUBLIC OF PANAMA
CARIBBEAN SEA
GOLFO DE LOS MOSQUITOS
COSTA RICA
Alto Lindo
CHIRIQUI
David
Puerto Armuelles
GOLFO DE CHIRIQUI
VERAGUAS
Sona
Santiago
Divisa
Rio Hato
Aguadulce
Golfo de Parita
RIO HATO MIL. RES.
COLON
Cristóbal
CANAL ZONE
Tocumen
Pacora
Chepo
Rio Bayano (Chepo)
PANAMA
Balboa
Panama Bay
SAN BLAS
La Palma
El Real
DARIEN
Jaque
COLOMBIA
GULF OF PANAMA
PACIFIC OCEAN
LOCATION MAP
0 30 60
MILES
PL - ESD

Figure 1



NLABS ESD CARTOGRAPHIC LAB

Figure 2

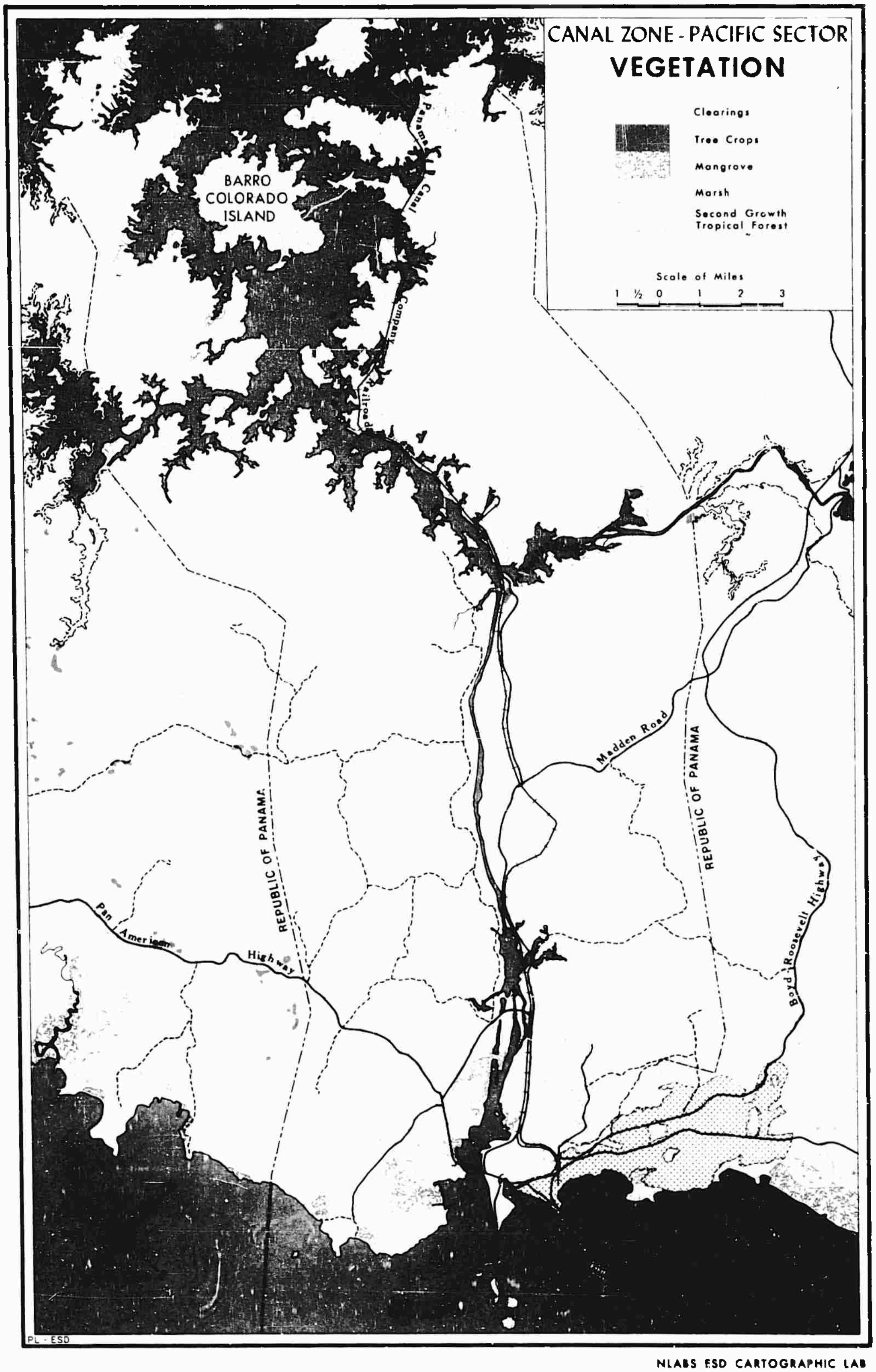
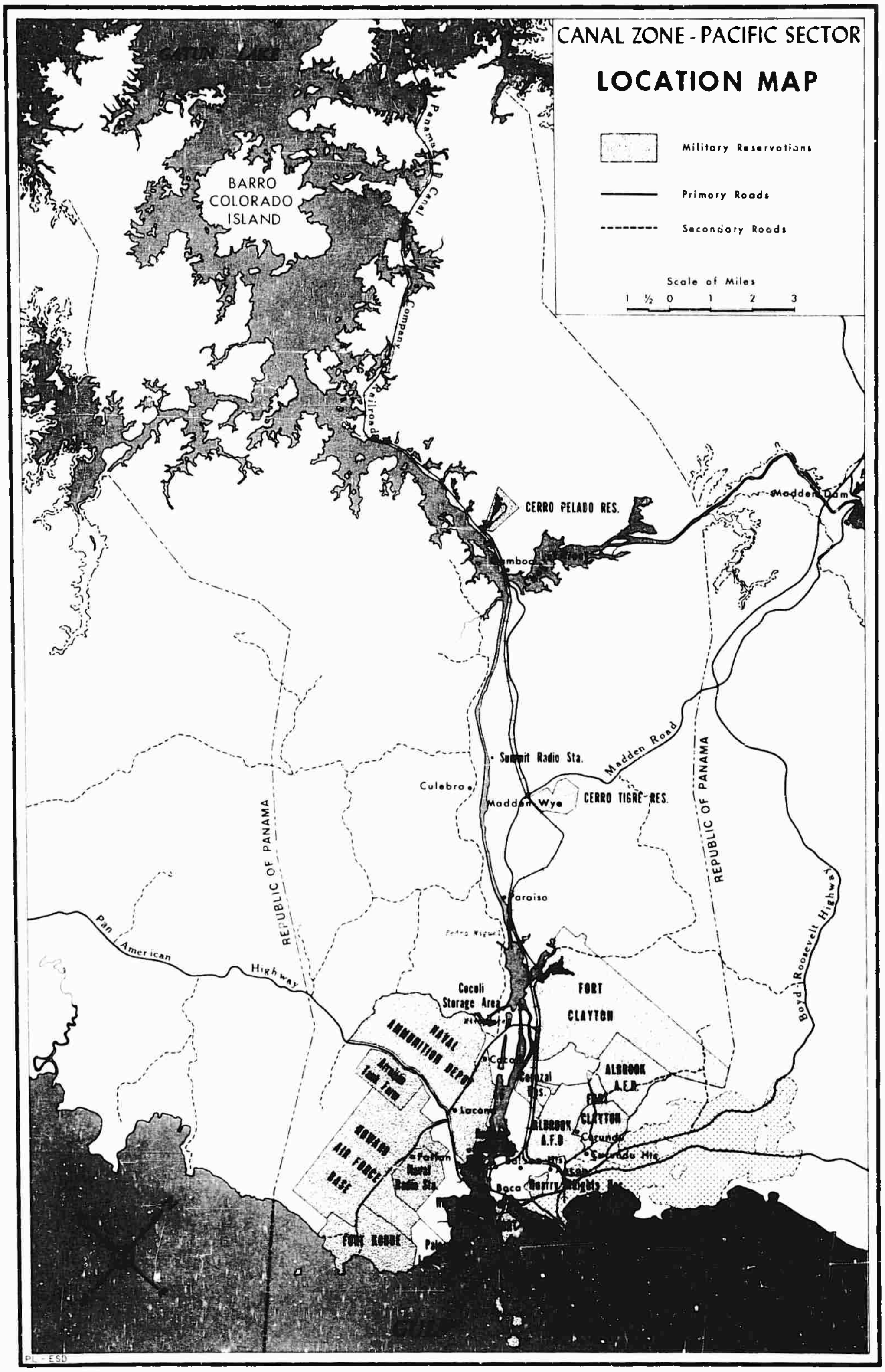

CANAL ZONE - PACIFIC SECTOR
VEGETATION
Clearings
Tree Crops
Mangrove
Marsh
Second Growth Tropical Forest
Scale of Miles
1 ½ 0 1 2 3
BARRO COLORADO ISLAND
Panama Canal Company Railroad
Madden Road
REPUBLIC OF PANAMA
REPUBLIC OF PANAMA
Pan American Highway
Boyd Roosevelt Highway
PL - ESD
NLABS ESD CARTOGRAPHIC LAB

Figure 3



NLABS ESD CARTOGRAPHIC LAB

Figure 4

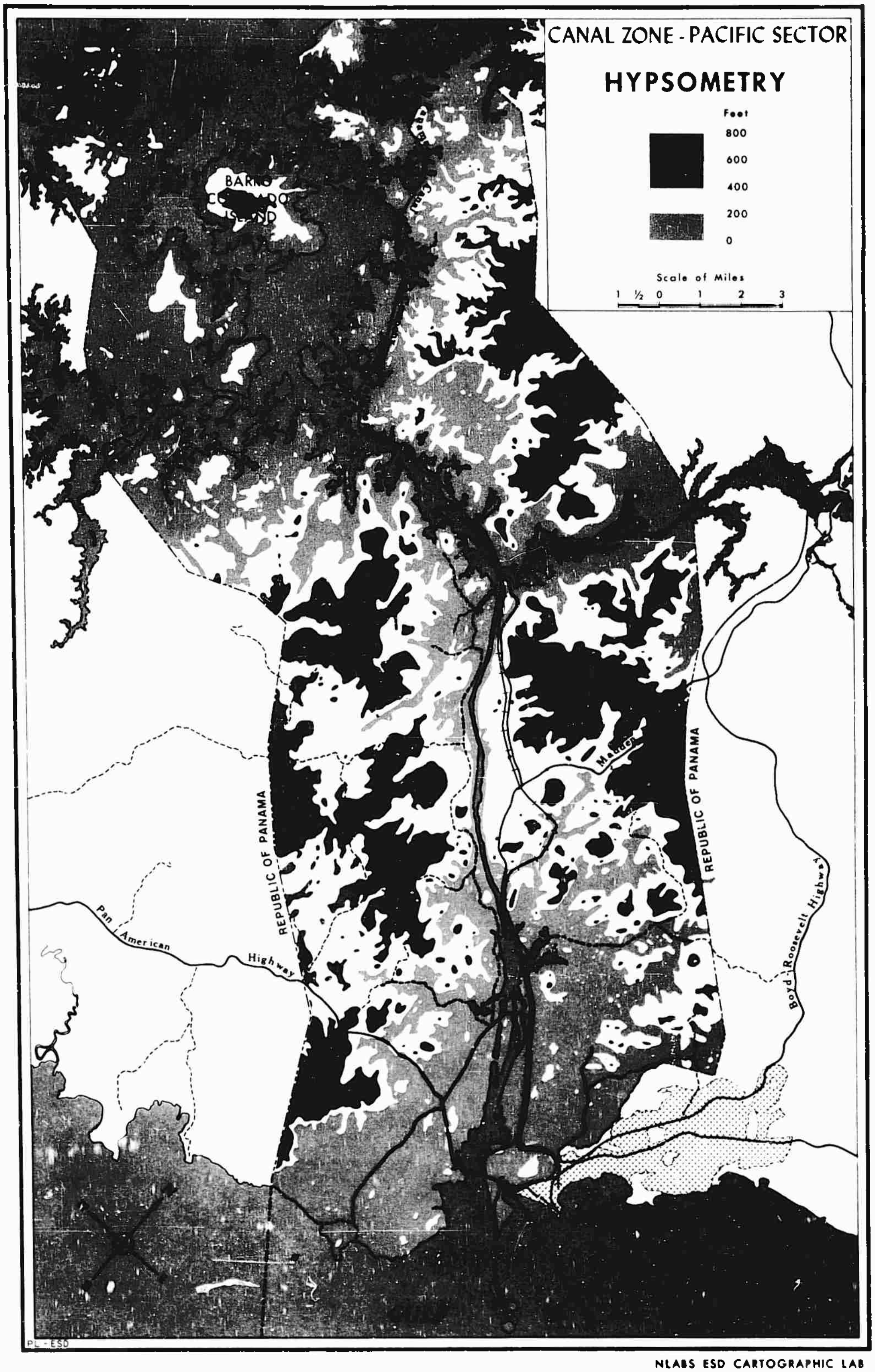

CANAL ZONE - PACIFIC SECTOR
HYPSOMETRY
Feet
800
600
400
200
0
Scale of Miles
1 ½ 0 1 2 3
REPUBLIC OF PANAMA
REPUBLIC OF PANAMA
Pan American Highway
Boyd-Roosevelt Highway
NLABS ESD CARTOGRAPHIC LAB

Figure 5

Regular training exercises are conducted by US Army units stationed in the Canal Zone at the Rio Hato Military Reservation. This reservation is 107 km (64 miles) west of the Canal Zone in the Republic of Panama. It is a grassland area, and is not representative of Canal Zone environments (see Appendix B).

2. Climate

a. Wet and Dry Seasons

The most significant aspect of the climate of the Isthmus of Panama is the marked change between the wet and dry seasons. The year is divided into a 4-month dry season (late December to late April) and an 8-month wet season. This is especially noticeable on the Pacific-facing slopes. This seasonal (wet and dry) aspect classifies the climate of the Canal Zone as typical of tropical savanna areas, rather than of tropical rain forest areas which have no dry season. However, climatic conditions characteristic of tropical rain forests exist in some areas of the Canal Zone during the wet season. Testing activities intended to show effects of tropical climates should be clearly designated for "wet" or "dry" season conditions since there are marked differences. Test results obtained during the dry season are not applicable to wet season conditions. Table I shows the marked difference between climatic conditions in the wet and in the dry season.

The following paragraphs and the graphs and tables in Appendix A describe the climate at Balboa Heights in the Canal Zone, and depict conditions which are generally representative of the climate on the Pacific side of the Isthmus. Balboa Heights is 118 feet above sea level in an area which has been cleared and cultivated. An area in the Canal Zone that is grassland, swamp or forest will give very different climatic data.

b. Temperature

Mean monthly temperatures vary from a low of 79°F in November, at the end of the wet season, to a high of 82°F in April, at the end of the dry season, an annual variation of 3 degrees (Table II). Thus, seasonal variations in the temperature regime are hardly noticeable (Fig. 6).* Daily minimum temperatures are 3 to 5 degrees lower during the dry season. A 1- or 2-degree increase in daily maximum temperatures is normally experienced at the end of the dry season and may extend into the first month of the wet season. Diurnal temperature ranges are low, and can be expected to vary slightly from day to day. On a typical dry-season day, the early morning minimum is about 76°F and the afternoon maximum about 85°F. The constancy of the temperature regime is further illustrated by the fact that the absolute range in this section of the Canal Zone is only 34 degrees; the absolute

*Note: Climatic graphs (Figs 6-27) are in Appendix A.

TABLE I. COMPARISON OF CLIMATIC DATA FOR DRY SEASON AND WET SEASON
BALBOA HEIGHTS, CANAL ZONE*

	Dry Season (Jan - Apr)	Wet Season (May - Dec)	Year
Temperature (°F)			
Mean	80.7	80.1	80
Absolute maximum	97	96	97
Absolute minimum	63	66	63
Mean daily range	17.2	12.8	14.3
Rainfall (inches)			
Mean	5.2	65.1	70.3
Mean deviation	2.8	8.0	8.5
Absolute maximum	13.82	90.06	91.42
Absolute minimum	0.16	43.99	45.58
Days with .01 inch	19	165	174
Humidity and dewpoint			
Humidity, mean daily (%)	77.0	87.3	83.8
Dewpoint	71.0	74.1	73.0
Wind			
Average speed (mph)	9.5	5.9	7.1
Prevailing direction	NE	NE	NE
Sunshine and cloudiness			
Sunshine (hr/day)	8.2	5.1	6.1
Cloudiness (%)	52	75	68

*Length of Record: 35 years; precipitation, 42 years (as of 1960).

TABLE II. TEMPERATURE (°F) BALBOA HEIGHTS, CANAL ZONE*

Month	Mean	Record Highest	Record Lowest	Mean Daily Range	Max above 85°F	Min below 75°F
Jan	80	93	63	16.6	30	30
Feb	80	95	64	17.8	27	27
Mar	81	96	65	18.1	30	30
Apr	82	97	64	16.2	28	24
May	81	96	69	13.0	28	20
Jun	80	95	70	12.2	27	24
Jul	81	95	67	13.0	27	24
Aug	81	94	68	12.9	24	28
Sep	80	94	68	12.3	18	26
Oct	79	95	68	11.9	19	29
Nov	79	94	67	12.4	18	29
Dec	80	94	66	14.5	26	30
Year	80	97	63	14.3	302	321

*Length of Record: 35 years (as of 1960).

minimum is 63°F, and the absolute maximum 97°F (Table I). Frequencies of extreme temperatures for two representative months, March (dry season) and October (wet season) are given in Appendix A (Figs. 7 and 8).

c. Precipitation

Rainfall is highly variable from year to year and from place to place (Fig. 9). For example, the average annual rainfall at Balboa Heights is 70.3 inches. However, the annual amount has varied from a high of 91.42 inches to a low of 45.58 inches (Tables I and III). The annual migration of the northeast trade wind belt in the inter-tropical front normally divides the year into a 4-month dry season (from late December to late April) and an 8-month rainy season (the remainder of the year). The mean precipitation for each of the wet-season months is in excess of 7 inches, and the actual total for a particular month may exceed 15 inches (Table III and Fig. 10). In both October and November, the peak of the wet season, more than 20 inches of rain have been recorded (Table III and Fig. 11). Of the dry months, February and March receive the least rain; the mean totals are 0.6 and 0.7 inch respectively.

However, the so-called "dry season" is a misleading term. During some years the dry season can be very dry (0.16 inch) and in others comparatively wet (13.8 inches, see Table I). For example, in December, monthly precipitation totals have ranged between 0.2 and 16.8 inches over a 42-year period (Table III). Rain may be expected any day during the dry season. One locality may receive as much as an inch of rain in a single storm while a neighboring area remains dry (see Figs. 12 through 23, Appendix A). Rainfall increases to the northwest, averaging 88 inches at Gamba, 117 inches at Monte Lirio, and more than 130 inches at Cristobal (Atlantic Sector). In addition to reporting less rainfall, the dry season in the Pacific Sector is approximately one month longer than in the Atlantic Sector.

d. Humidity and dew

The relative humidity is notably high, varying from an average in the high 70's in February and March to the middle 80's from April through January (Table IV). During the latter months the average for the early morning hours is above 90 percent. Variations in relative humidity between similar environments are negligible. However, great differences (20 to 40 percent) may be observed between a forest environment and an adjacent clearing.

Humidity increases rapidly with the onset of the rainy season when the average relative humidity is 95 percent or more at night, decreasing to a mean of 75 percent in the mid-afternoon. During the dry season, the morning and the afternoon relative humidities average 10 to 15 percent lower than

TABLE III. PRECIPITATION (INCHES) BALBOA HEIGHTS, CANAL ZONE*

Month	Mean	Max Monthly	Min Monthly	Max Daily	Max Hourly	Number of Days with at least .01 in.	.25 in.	1 in.
Jan	1.0	5.6	0	2.1	2.0	6	1	0
Feb	0.6	2.9	0	2.2	1.5	3	1	0
Mar	0.7	5.7	0	2.4	2.1	2	1	0
Apr	2.9	7.7	0	3.1	2.5	8	3	1
May	8.0	13.1	3.3	7.2	3.5	19	8	2
Jun	8.4	18.3	2.5	6.4	3.8	20	8	2
Jul	7.3	15.8	3.1	3.5	2.5	19	8	2
Aug	7.8	15.2	1.4	4.1	2.8	19	8	2
Sep	8.2	16.3	3.2	4.2	2.6	20	8	2
Oct	10.2	20.2	4.3	4.6	3.9	21	10	3
Nov	10.5	20.5	3.5	6.3	3.3	22	10	3
Dec	4.7	16.8	0.2	4.3	1.9	15	6	2
Year	70.3	20.5	0	7.2	3.9	174	72	19
Absolute		91.42	45.58					

*Length of record: 35 years; daily precipitation, 42 years (as of 1960).

TABLE IV. RELATIVE HUMIDITY (%), BALBOA HEIGHTS, CANAL ZONE*

Month	Mean	0600 hours	1400 hours	2200 hours
Jan	80	91	61	87
Feb	76	88	56	84
Mar	75	87	55	82
Apr	77	88	60	83
May	85	92	73	90
Jun	87	94	75	92
Jul	87	94	76	92
Aug	88	95	76	92
Sep	87	95	74	91
Oct	88	94	78	93
Nov	88	94	77	93
Dec	85	93	70	91
Year	83.8	92	69	89

*Length of Record: 35 years (as of 1960).

in the wet season. In general, the areas of lowest humidity are those with the least rainfall. At Balboa Heights, for example, the lowest (1400 hours) mean humidities occur in February and March (the months of lowest rainfall), with 56 and 55 percent respectively reported (Fig. 24).

Dewpoints show a similar trend from dry season to wet season, maximums ranging from 73°F in March to 86°F in July (Fig. 25). Dew may be observed any morning during the dry season.

e. Winds

The dry season is dominated by the northeast trade winds, with the northern component prevailing (Table V). Mean monthly windspeeds are highest during this period. February and March each have 10 mph averages (Table V and Fig. 26). By May the Zone of Doldrums has moved northward into this region and the winds become light and variable, averaging approximately 6 mph. In the forested areas winds are less than 3 mph in each season. The highest winds, from 10 to 19 mph, are experienced on the deforested basaltic domes throughout this part of the Canal Zone.

Winds during the wet season continue from the northeast, but the easterly component prevails. An increase in wind speeds usually occurs in December as the Zone of Doldrums moves toward the south.

f. Cloudiness, sunshine, and radiation

During the wet season more than 5 tenths of the sky is covered by clouds 85 to 90 percent of the time, and during the dry season this occurs about 50 percent of the time (Table I). Daytime cloudiness averages about 7 tenths of complete sky coverage annually.

Although the percentage of cloudiness is high, there are few days without some sunshine. Balboa Heights averages 6.1 hours of sunshine per day or approximately 50 percent of the possible amount, with monthly totals ranging from about 5 hours per day in June, July, and November to about 9 hours per day in January and February (Table V). Clouds usually move rapidly through the sector.

Open area radiation values vary from 300 to 600 langleys per day in the wet season, and from 400 to 600 langleys per day in the dry season. In wooded areas radiation values are low throughout the year, averaging 2 to 25 langleys per day.

TABLE V. WIND, CLOUDINESS AND SUNSHINE, BALBOA HEIGHTS, CANAL ZONE*

Month	Wind (mph) Mean Speed	Wind (mph) Max Speed	Cloudiness (no. days) Clear	Cloudiness (no. days) Partly Cloudy	Cloudiness (no. days) Cloudy	Sunshine Average Hours	Sunshine % of Possible
Jan	8.8	17.0	9	20	2	8.7	74
Feb	10.1	19.1	8	18	2	8.8	75
Mar	10.3	19.2	7	22	2	8.5	72
Apr	8.8	17.9	2	20	8	6.7	56
May	6.1	13.7	0	13	18	5.0	42
Jun	5.4	12.8	0	10	20	4.6	38
Jul	5.9	13.8	1	12	18	4.9	41
Aug	5.9	13.8	0	13	18	4.8	40
Sep	5.6	13.5	0	12	18	4.8	40
Oct	6.3	13.9	0	12	19	4.9	41
Nov	5.8	14.0	1	12	17	4.0	42
Dec	6.4	14.1	3	19	9	6.7	56
Year	7.1	15.2	31	183	151	6.1	50

*Length of Record: 35 years (as of 1960).

g. Visibility

Visibility in open areas is equal to or greater than 6 miles for more than 90 percent of the time. The major obstruction to visibility is rain; other obstructions, such as fog, smoke, haze and dust, are rare in the rainy season. Small clouds are frequently formed by condensation of "steam" just above the tree tops. This is particularly noticeable in forested valleys. Clouds of smoke are frequently encountered outside of the Canal Zone near agricultural settlements during "field burning" operations. Within forests, horizontal visibility is normally less than 50 feet. In dense vegetation areas in former forest "clearings" (such as in stands of capulin, Trema micrantha), visibility may be less than 10 feet.

h. Storms

The onset of the rainy season is characterized by an increase in the number of storms (Fig. 27). During the dry season only an occasional cold air mass, accompanied by widespread cloudiness, low ceilings and visibilities, and rain showers, penetrates as far south as the Canal Zone. However, thunderstorms occur frequently during the wet seasons from May through November (Table VI). During these 7 months an average of 80 (of the annual average of 89) storms occur. At times the thunderstorms are very intense, with strong, gusty winds and severe lightning, but damage to buildings is seldom reported. Hurricanes, common in the Caribbean, have never been reported in the Canal Zone.

i. Microclimate of forest areas

Climatic data given for Balboa Heights reflect conditions in an open environment. Significant differences in the above data will be noted where measurements are taken in a forested area. Within the forests, temperature, humidity, wind and radiation conditions differ greatly from those in the open. Ground surface temperatures as high as 130°F have been measured in an open area at Miraflores when air temperatures at the 6-foot height were 87°F or slightly lower. With the same 6-foot air temperature (87°F), the ground surface temperatures within a closed canopy forest were 73 to 76°F.

One of the most notable microclimatic features of the tropical forest is the stillness of the air. For example, at Barro Colorado Island during a 3-week test period, average wind movement at 6 feet above the ground in

TABLE VI. MEAN FREQUENCY OF OCCURRENCE (DAYS) OF THUNDERSTORMS, FOG AND SUNSHINE, BALBOA HEIGHTS, CANAL ZONE

Month	Thunderstorms	Light Fog	No Sunshine	90% Sunshine
Jan	1	0.1	0	27
Feb	0	0.1	0	27
Mar	1	0.1	0	18
Apr	4	0	1	10
May	10	0	5	1
Jun	12	0.1	6	1
Jul	12	0.2	5	1
Aug	14	0.1	5	1
Sep	13	0.1	5	1
Oct	11	0.3	5	1
Nov	8	0.4	5	4
Dec	3	0.1	2	11
Total	89	1.6	39	103
Monthly Mean	7.3	0.1	3.2	8.6

the forest was less than 1 mph. Average wind speed in a nearby open area was 10 mph. Humidities within the sheltered stillness of the forest are high, creating an oppressiveness which could be of primary concern in test planning. Also, of course, all plans for testing in forest areas should include provision for on-the-spot meteorological observations at several different heights above the ground.

3. Surface and Terrain

a. Basaltic hills

The Pacific side of the Isthmus is characterized by a series of eroded benches interrupted by numerous isolated knolls or knobs of intrusive basaltic rock which rise 250 to 650 feet above the coastal plain (see Fig. 5). Exposure of basalt may be found near the bases of the knolls, such as in places where this rock has been quarried for crushing, but elsewhere hill slopes consist of a heavy, red lateritic clay.

Many of the steep slopes that seem to be characteristic of this environment may be due to the tendency of the basalt to weather in steep columns; on the other hand, the softer depositional material of the bench is easily eroded. The hardness of the basalt permits the columnar structure to resist the mechanical weathering of fast-flowing streams that cut deep into the softer materials. The islands in Panama Bay reflect a continuation of this knobby topography onto the continental shelf.

b. Benches and terraces

Fort Kobbe, Balboa and Ancon in the Canal Zone lie on top of an eroded coastal bench consisting of tuff and agglomerate. The outer edge of this coastal bench is an indefinite scarp that varies in height from 10 to 20 feet above the beach.

In Fort Kobbe a bench cut in basaltic rocks fringes steep-sided knolls. Near Howard Air Force Base the bench borders an inlet of mangrove swamp drained by the Rio Venado. The seaward edge of the swamp ends in a sand ridge beyond which spread mud flats, beaches of scattered boulders and exposed bedrock. At Dejal Beach, Fort Kobbe, the sand beach is fringed on its seaward side by a rocky marine platform and is backed by a cliff cut into the bedrock that marks the outer edge of a low, weathered bench. The inner edge of this low bench merges with the higher one on which Fort Kobbe is located.

East of the ruins of Old Panama, along the route followed by several U. S. Army vehicular-evaluation projects, the composition of the bench changes from volcanic tuffs and agglomerate to sandstone and siltstone (on the route from Tocumen to Chepo). The bench has a gently rolling surface, covered with thin patches of alluvium, above the slightly entrenched streams. Weathered bedrock can be seen in shallow road cuts. Here the outer edge of the terrace is fringed by a swampy grassland which changes to mangrove (swamp) near the sea. Sand ridges rise above both the grass and mangrove swamps.

The alluvium on the Pacific bench grades from coarse gravel to silt on the interfluves. In many places the steep outer edge of the bench is cut by waves and appears as sea cliffs or sand ridges. Good evidence of the drowning of erosional topography is seen by the broad deposits of new mud exposed at low tide, and the deterioration of old mud flats left standing above the new mud.

c. Mud flats

Wide mud flats fringe that portion of the Pacific coast with high tidal ranges (15 to 20 feet). Mud from streams and offshore currents is carried in by high tides and is deposited on the beach during slack periods as the tide turns. The source of mud along the Pacific coast appears to be largely local because both the Aguadulce and the Pacora mud flats border low erosional plains drained by sluggish rivers. Mud is found on the floor of the Gulf of Panama for 45 miles seaward of the mean shore line. Coastal benches and beach terraces are fringed by broad expanses of mud and bedrock flats that are exposed at low tide. This mud consists of organic black silt sediment and includes wood and other semi-decayed vegetable matter. It occurs in deposits 40 feet or more thick and extends from outside the Pacific entrance of the Canal inland to Miraflores Lock.

Near Pacora the mangrove belt is narrow and bordered by erorded mud flats. Cakes of old mud, still supporting thin stands of mangrove, stand sharply above the younger mud flat that extends for more than a mile from shore during low tide. The entire zone of swamps, sand ridges, and mud flats increases in width eastward toward the mouth of the Rio Chepo O'Bayano. West of Old Panama the trend of the coastline corresponds to the outer edge of the bedrock bench.

The relatively cool Pacific waters, especially in the months from January to April, apparently suffice to prevent development of coral reefs near the shore. Great deposits of mud along the Pacific coast and the fresh water at the mouths of the larger rivers may be added causal factors. However, even where the mud flat is absent, as along the coast at Rio Hato, reef corals do not grow.

4. Vegetation

a. Tropical deciduous forest

The drier climate on the Pacific slopes (as compared with the Atlantic), together with annual burning of grasses and trees for new fields, has made a marked difference in the vegetation on the Pacific side of the Isthmus. Large trees are more widely spaced and the understory vegetation thickens because of the greater sunlight and slightly drier conditions (Fig. 3). Centuries of cut-and-burn agriculture (potrero) have changed the appearance of the vegetation in this area into a type of grassland not normally found in this type of climate. There are numerous patches of trees in the clearings containing such species as chumica (*Curatella americana*), acacia, trumpet trees, together with several types of grasses, sedges, and small herbs. During the rainy season the grasses grow rapidly and form a thick cover over the ground, ranging from 1 to 4 feet or more in height. In the dry season these grasses turn brown and are usually burned off.

The nearest area with vegetation conditions approximating that of a true tropical rain forest is Barro Colorado Island. This island is occupied by the Institute of Tropical Research which restricts the type of studies conducted on the island. In the Madden Road Forest Preserve, which is also restricted, and on the eastern slopes of Gigante, Viejo, and Balboa mountains, unrestricted to use for approved military activities, are relatively untouched forests. These forests contain hundreds of species.

The diameters of the tree trunks vary from 5 to 15 feet for the giant cativo (*Prioria copiaflora*), and giant fig trees (*Ficus glabrata*). The big trees are generally from 20 to 50 feet apart, but appear to be much closer because of their buttressed root systems. Large trees, from 100 to 150 feet tall, dominate other forms of vegetation in these forests. Most of these trees do not branch except near their crowns. Their crowns appear to form a continuous canopy with only an occasional tall tree rising above the general level.

Below the upper, or main canopy, there is often a second-story canopy which is more widely spaced and consists of smaller immature cativos, cuipos, trumpet trees and small black palms. Most of these trees are less than 30 feet tall and many of them have trunks only a few inches in diameter. The trunk of the black palm is ringed with long sharp thorns and needle-like barbs. Its wood is heavy and so difficult to cut that it is frequently left standing after other trees have been cleared. This second-story vegetation has very little effect on visibility or trafficability inside the forest. Usually the vegetation can be easily pushed aside or quickly removed with a machete. Mahogany trees are scattered throughout the forest, not in dense stands but averaging one big tree per acre in the wet-and-dry deciduous forest. Because of the abundant rainfall and resulting rapid growth of trees, the mahogany wood is very light in weight, and therefore classified as low grade.

Vines, lianas, orchids, vanilla, philodendron, and other parasitic plants grow on the trunks and branches of trees. The flora of the forest floor is limited to those species requiring a minimum of light, soil nutrients, and root space, e.g., lichens, moss, and ferns. In the openings and clearings, where sunlight penetrates to the forest floor, are thickets of heliconia, various palms, coarse grasses and herbaceous plants. This condition prevails near roads and in slightly drier environments. It causes the forest to appear impenetrable. Also, clumps of saw-grass with sharp-edged blades grow along established trails.

b. Clearings

Temporary clearings and fields left fallow soon develop dense growths of scrub and coarse weedy shrubs. Examples of such fields are seen at abandoned firing ranges, old test sites, and other locations once cleared for use and later abandoned. From a distance these former clearings appear as stair-steps of vegetation, their respective heights reflecting the number of years since the area was abandoned.

Small patches of woodland have been cleared by farmers practicing primitive shifting cultivation (campesinos). Trees were cut down and burned in the dry season and staple crops were grown in the rainy season. Crops grown include: corn, rice, beans, coffee, sugar cane, banana, pineapple, avocado, mango, onions, melon, papaya, plantain, breadfruit, tomatoes, peppers, garbanzas, guavas, citrus fruits and numerous root crops such as yuccas, otes, name, and sweet potatoes. Many of these food crops grow in the forest in a semi-wild state. In most instances these plants are relic or volunteer remnants of formerly cultivated tracts. The clearings were used only 2 or 3 years for crops and were sometimes planted to guinea or para grass and used for grazing. The area then becomes an artificial llanos (savanna).

There are close-cut lawns, clipped shrubbery, and well-tended trees around permanent installations. Even here, however, natural growths of vegetation remain in inaccessible gulleys or along steep slopes. Around the regularly tended grounds there is a transitional zone of scrubby marginal growth where the vegetation is subject to clearing in alternate years or at infrequent intervals. At present, no new areas are being opened to cultivation.

The courses of succession on old clearings begin with grasses, abandoned sedges, and a variety of broad-leaved herbs. However, most of these pioneers are short-lived. Plants such as the heliconias and the Panama-Hat palm appear after a year, together with numerous seedlings of the trees that will dominate later. Also, thorny lianas become established, making this vegetation an impenetrable tangle. Trees become dominant after 2 years, forming a young secondary forest. Additional species invade the area and the vegetation takes on the aspect of a typical wet-and-dry forest. In succeeding years this vegetation becomes more dense and more difficult to penetrate than the primary forest, until the undergrowth and smaller trees are shaded out.

c. Coastal swamps

When fresh water covers the land, thick stands of palm swamps (Manicaria, raffia) are found. These are relatively low, only 6 to 15 feet high, but too thick to traverse easily. At several spots along the coast and above the high-tide line there is a dense underbrush consisting of coconut palm, sea grapes, manhoe (Hibuscus tiliaceas), and several kinds of shrubs. This brush rarely exceeds 25 feet in height. Swamps are found along the shore of Gatun Lake and mangrove occurs in some salt water areas that are sheltered from the surf. The mangrove is 20 to 40 feet tall and has multiple trunks, which are 6 to 10 inches thick and are supported by stilt roots (Fig. 34).

5. Insects and Reptiles

Mosquitoes in the Canal Zone are not a serious problem since there are extensive control measures. Outside the Zone fine mesh mosquito nets are required around sleeping areas to protect not only against mosquitoes, but also sand flies, flying ants, hornets, wasps and gnats. Both forest and savanna areas are infested with spiders, ticks, chiggers, mites, fleas, lice, and several types of ants. Swarms of tiny stinging ants as well as large warrior ants may be encountered when hollow trees are cut. Leaf-cutter ants are found in all parts of the Zone.

There are three main families of poisonous snakes in Panama; the pit vipers, corals, and sea snakes. The vipers include: fer-de-lance, bushmaster, tree vipers, and the tropical rattlesnake. Fifty species of sea snakes are found in Panama, and are frequently caught in fish nets. They grow from 1 to 3 feet long. The coral snake is 10 to 20 inches long. Its basic color is red with black bands bordered by yellow or white. It is a burrowing snake, and is found under large leaves in forest litter. Rattlesnakes are found in the relatively dry tablelands of Chiriqui and Veraguas Provinces of the Panama Republic but not in the Canal Zone. They resemble mid-latitude rattlesnakes, but their venom is considered to be far deadlier. The fer-de-lance frequents lowland plantations in search of rodents that live on fruit. This snake is slender, dark, often black, with yellow or gray "X" designs on its back, and is approximately 5 feet long when fully grown. The bushmaster has a thick body, about the size of a man's leg, and grows to between 7 and 14 feet long. Its general body color is tan, with a black saddle-like pattern on its back. It lives in rocky forested areas. There are three small tree vipers in Panama: the eyelash snake, jumping snake, and Godman's viper. Each is 10 to 20 inches long. The eyelash snake is olive green with pink or black dots on its back. The jumping snake has a very thick body with a double saddle-and-stirrup pattern in tan and black on its back. Godman's viper is black. The tree vipers have dart-shaped heads. They inhabit the vines along trails, and may be found in stacks of supplies or piles of building materials.

Mango snakes and boa constrictors are common in forested areas in Panama and, while not poisonous, may inflict an infectious bite. Most encounters with snakes can be avoided by beating the trail-side vegetation with a 4- or 5-foot pole.

6. Summary

The Pacific Sector, Canal Zone, contains numerous favorable areas for training or testing under both wet tropical and dry tropical conditions, depending on the season. The climate is typical of the wet margin of tropical savanna areas with distinct wet and dry seasons. The average annual precipitation is 70.3 inches, of which more than 90 percent falls during the 8-month wet season (mid-April to mid-December). The mean relative humidity for the wet season exceeds 85 percent. The average monthly rainfall is 0.6 inch in February (dry season) contrasting with 10.5 inches in November, the wettest month. The northeast trade winds blow steadily during the relatively dry season from mid-December to mid-April. The Pacific Sector is markedly drier throughout the year than is the Atlantic Sector. The dry season is at least one month longer, has lower minimum temperatures and more sunshine than the same season in the Atlantic Sector.

The terrain consists of hundreds of intrusives, dome-like basaltic hills, surrounded by a gently sloping platform of sedimentary materials. Nearly all these hills have steep slopes and rounded tops with summit elevations between 250 and 650 feet. The coastal area is characterized by a series of benches and terraces bordered by low, steep cliffs interrupted by hills and sandy beaches.

A tropical deciduous (wet-and-dry) forest with a great variety of species dominates the vegetation in the upland areas. Mangrove swamps are found in the coastal areas near Fort Kobbe and adjacent to the entrance to the Panama Canal at Miraflores. Various marsh plants and grasses cover the remainder of the lowlands and the frequently flooded areas. Rain forests do not occur in this part of the Canal Zone but personnel conducting tests in the wet-and-dry forests during the rainy season may experience environmental conditions similar to those in rain forests.

Testing or training activities may be conducted in nearly all parts of the Canal Zone. For example, approved large-scale testing may be staged in the unused forest areas inland from the coast. Many small patches of forest as well as clearings inside military installations may be used for small-scale testing. Restricted areas, or areas requiring special permits for use, include the Empire Range, Venado Beach Range Area, Barro Colorado Island, and Madden Road Forest Preserve. Land licenses must be obtained from the USARSO Engineer for all military use of land in the Canal Zone.

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8. Acknowledgments

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APPENDIX A

CLIMATIC GRAPHS FOR BALBOA HEIGHTS*

*See "List of Figures" at beginning of report

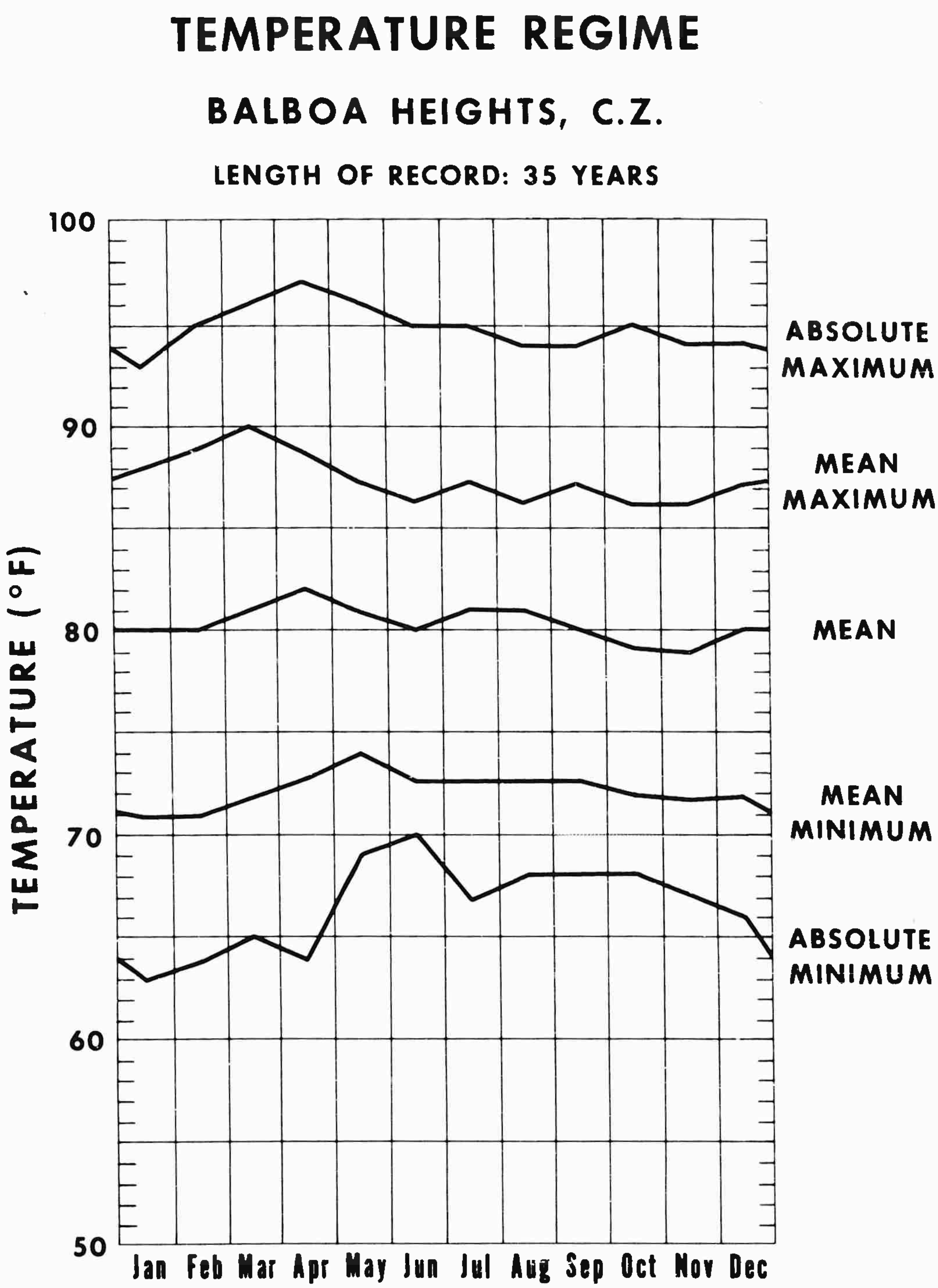
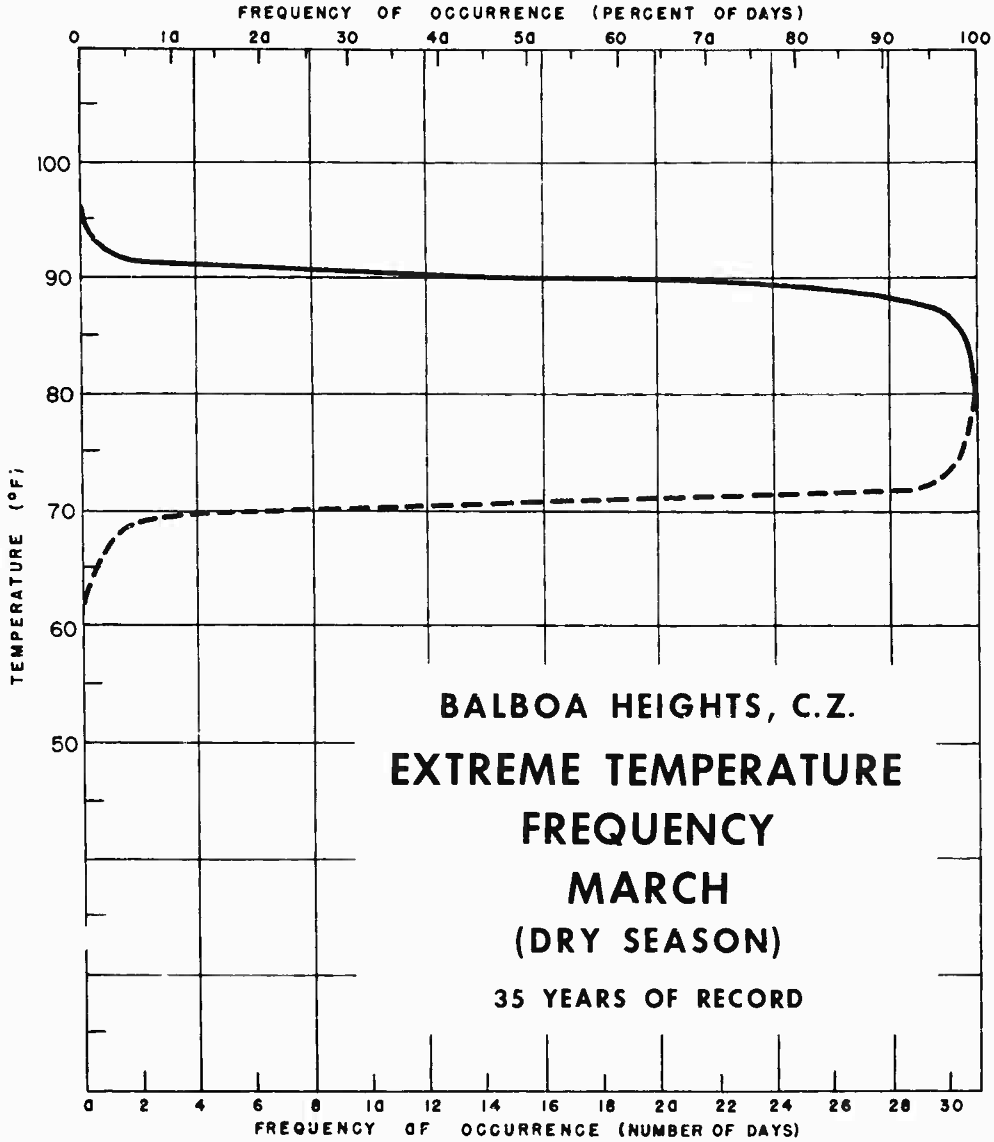

TEMPERATURE REGIME
BALBOA HEIGHTS, C.Z.
LENGTH OF RECORD: 35 YEARS
100
90
80
70
60
50
TEMPERATURE (°F)
ABSOLUTE MAXIMUM
MEAN MAXIMUM
MEAN
MEAN MINIMUM
ABSOLUTE MINIMUM
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 6

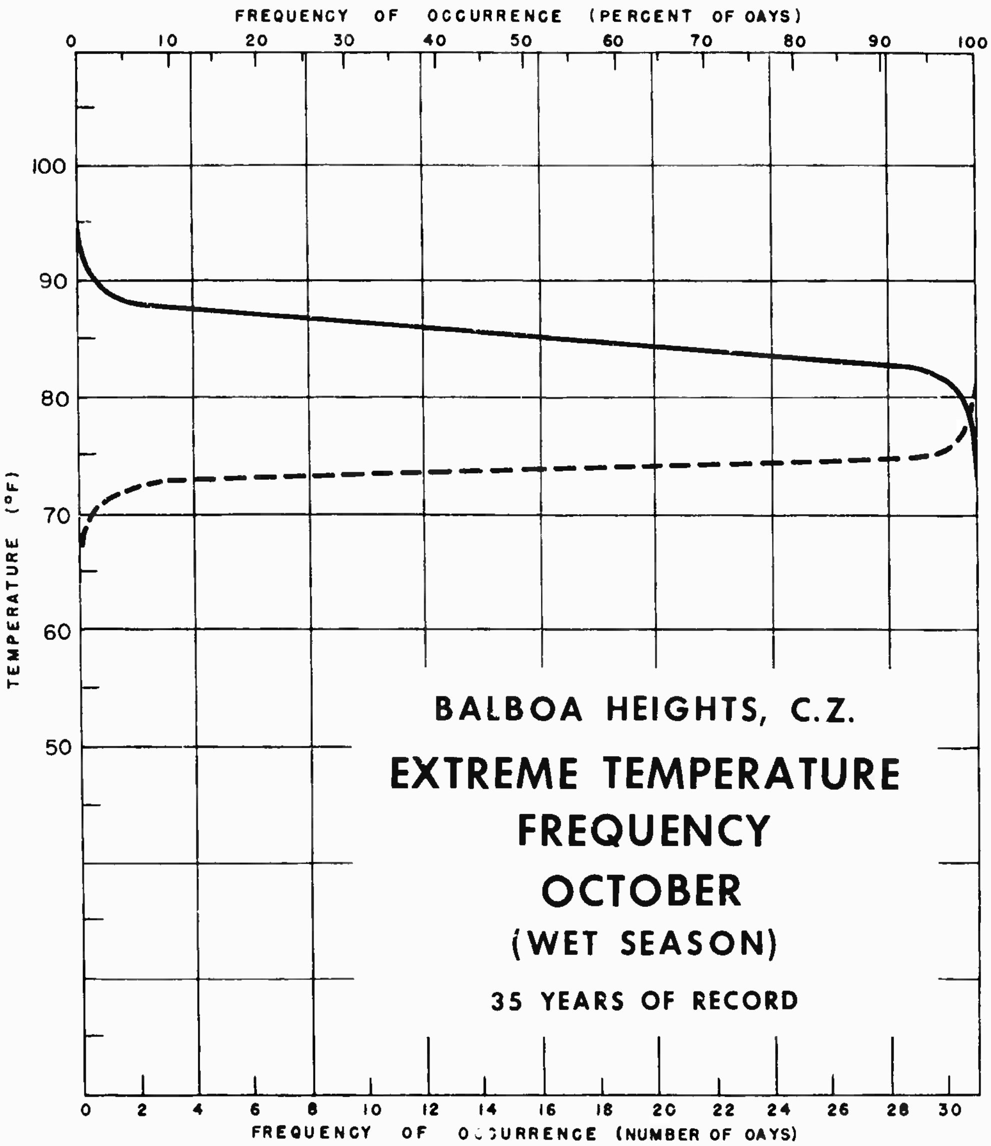


—— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

– – – Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 90°F or greater may be expected to occur 15 days during March (or approximately 50% of the days).

Figure 7



——— Number of days (or percent of days) the daily maximum temperature may be expected to equal or be greater than a particular temperature.

- - - Number of days (or percent of days) the daily minimum temperature may be expected to equal or be less than a particular temperature.

Example: A maximum temperature of 86°F or greater may be expected to occur 15 days during October (or approximately 50% of the days).

Figure 8

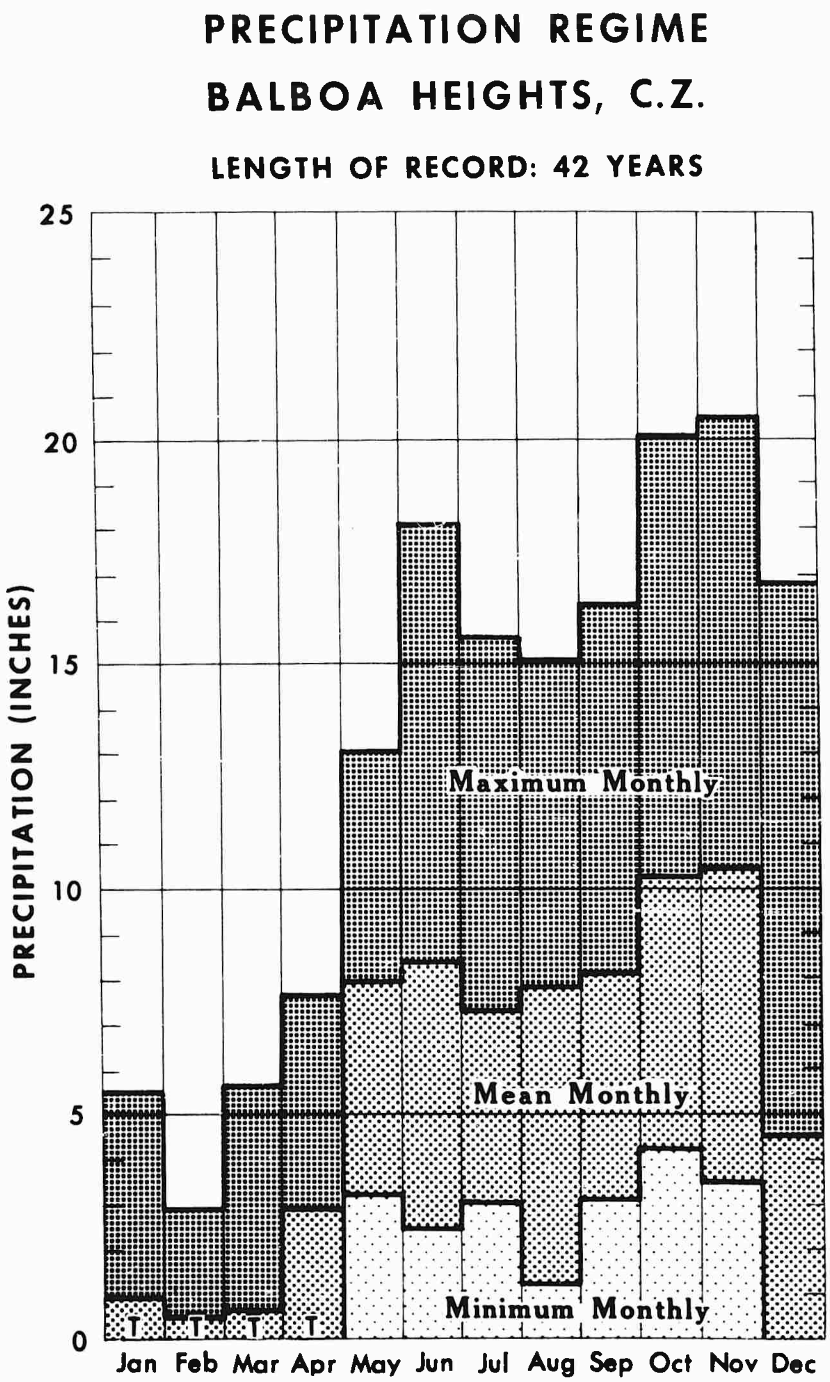

PRECIPITATION REGIME
BALBOA HEIGHTS, C.Z.
LENGTH OF RECORD: 42 YEARS
25
20
15
10
5
0
PRECIPITATION (INCHES)
Maximum Monthly
Mean Monthly
Minimum Monthly
T
T
T
T
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec

Figure 9

TRENDS OF DAILY PRECIPITATION AT BALBOA HEIGHTS

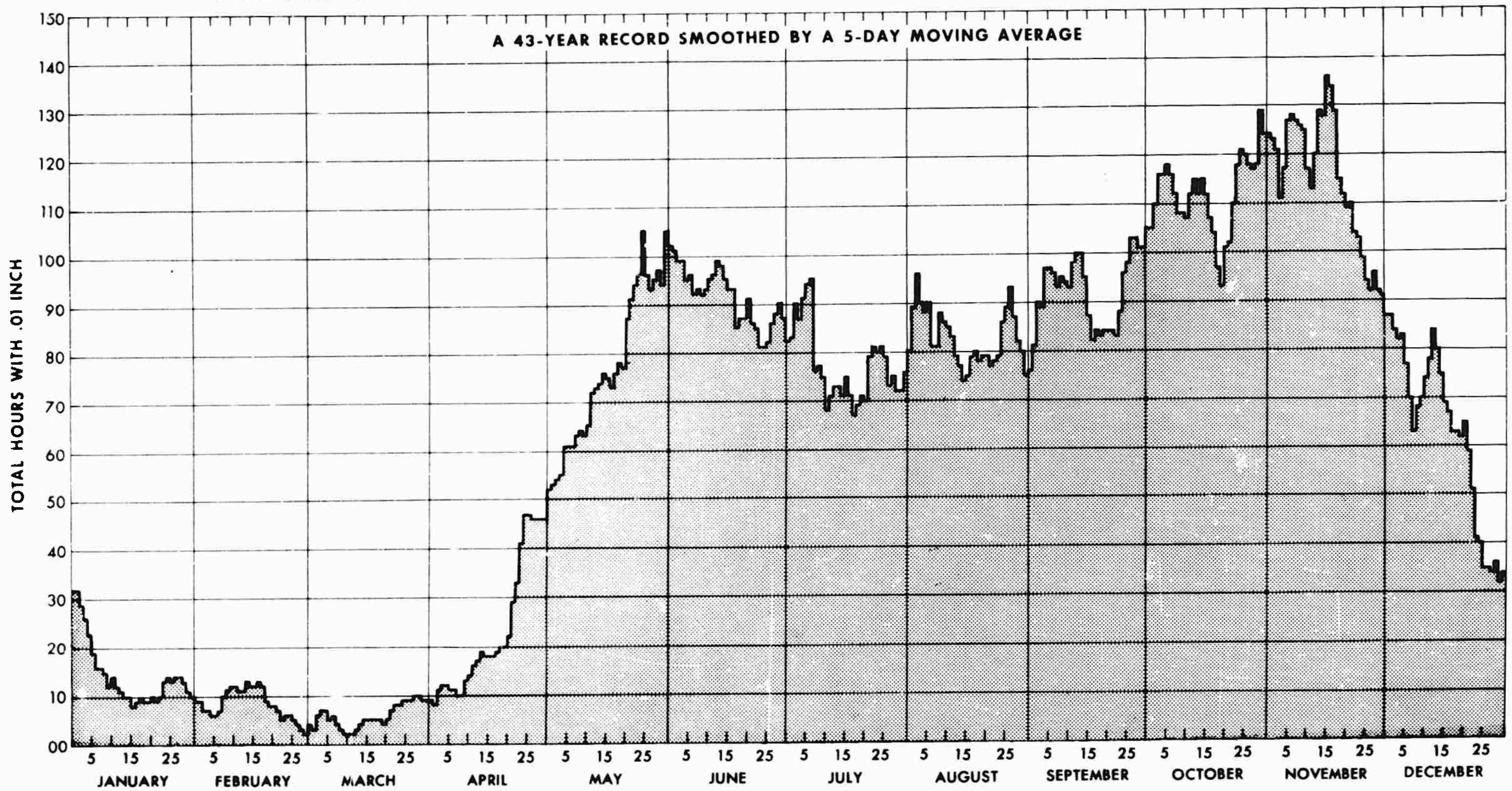
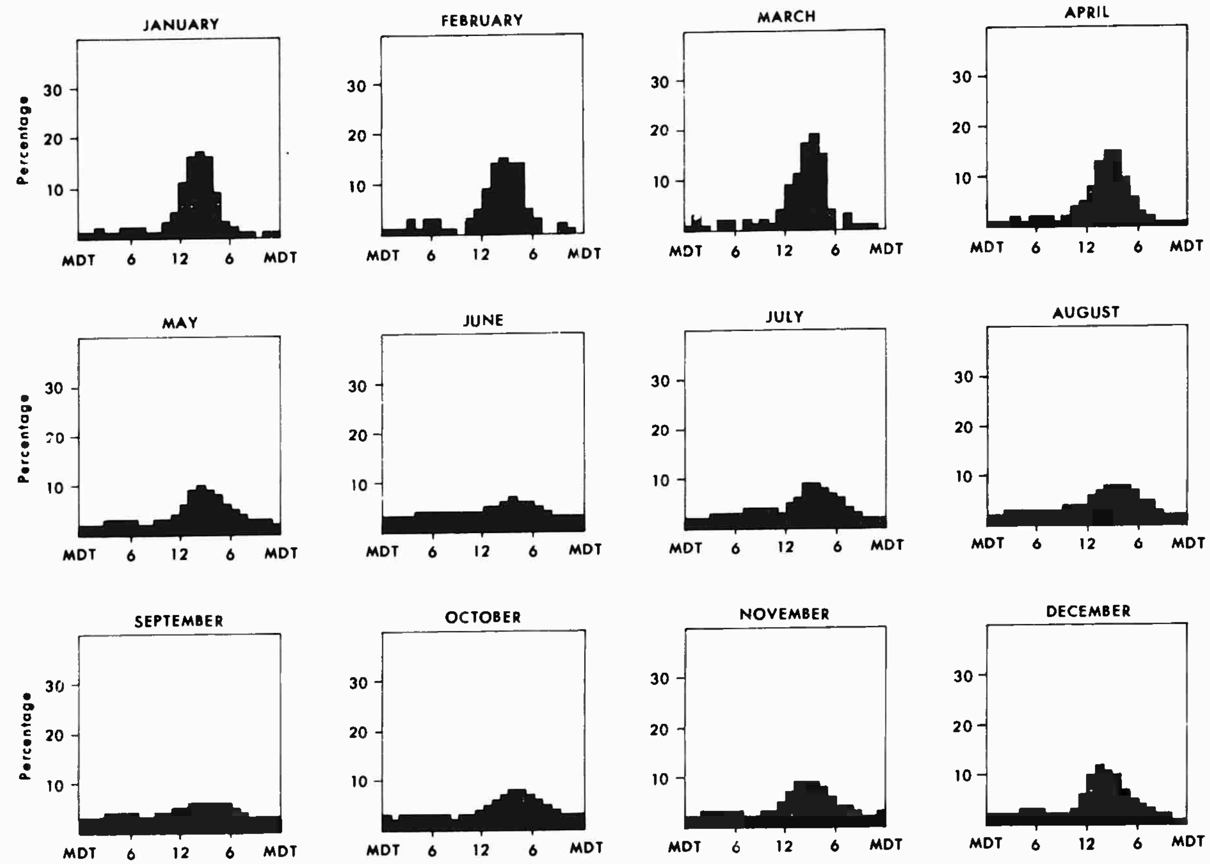


Figure 10

HOURLY PERCENTAGE DISTRIBUTION OF RAINFALL AT BALBOA HEIGHTS, C.Z.

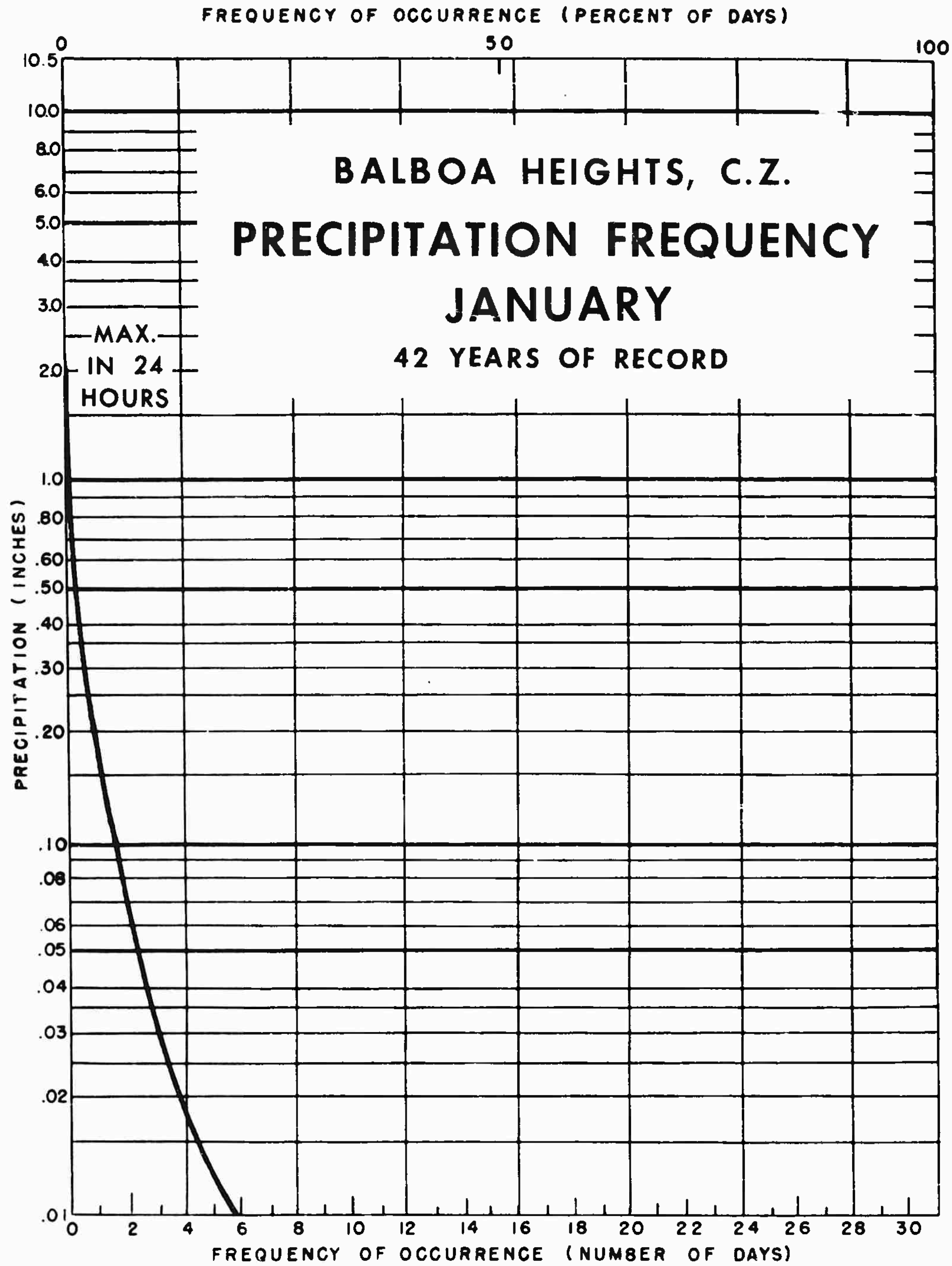
44 YEARS OF RECORD - 1906 TO 1949



HOURLY PERCENTAGES ARE GIVEN FOR EACH HOUR AND ARE THE PERCENTAGES OF THE MONTHLY TOTAL HOURS OF RAIN EQUALING OR EXCEEDING .01 INCH PER HOUR, FOR 44 YEARS OF RECORD.

PL - ESD

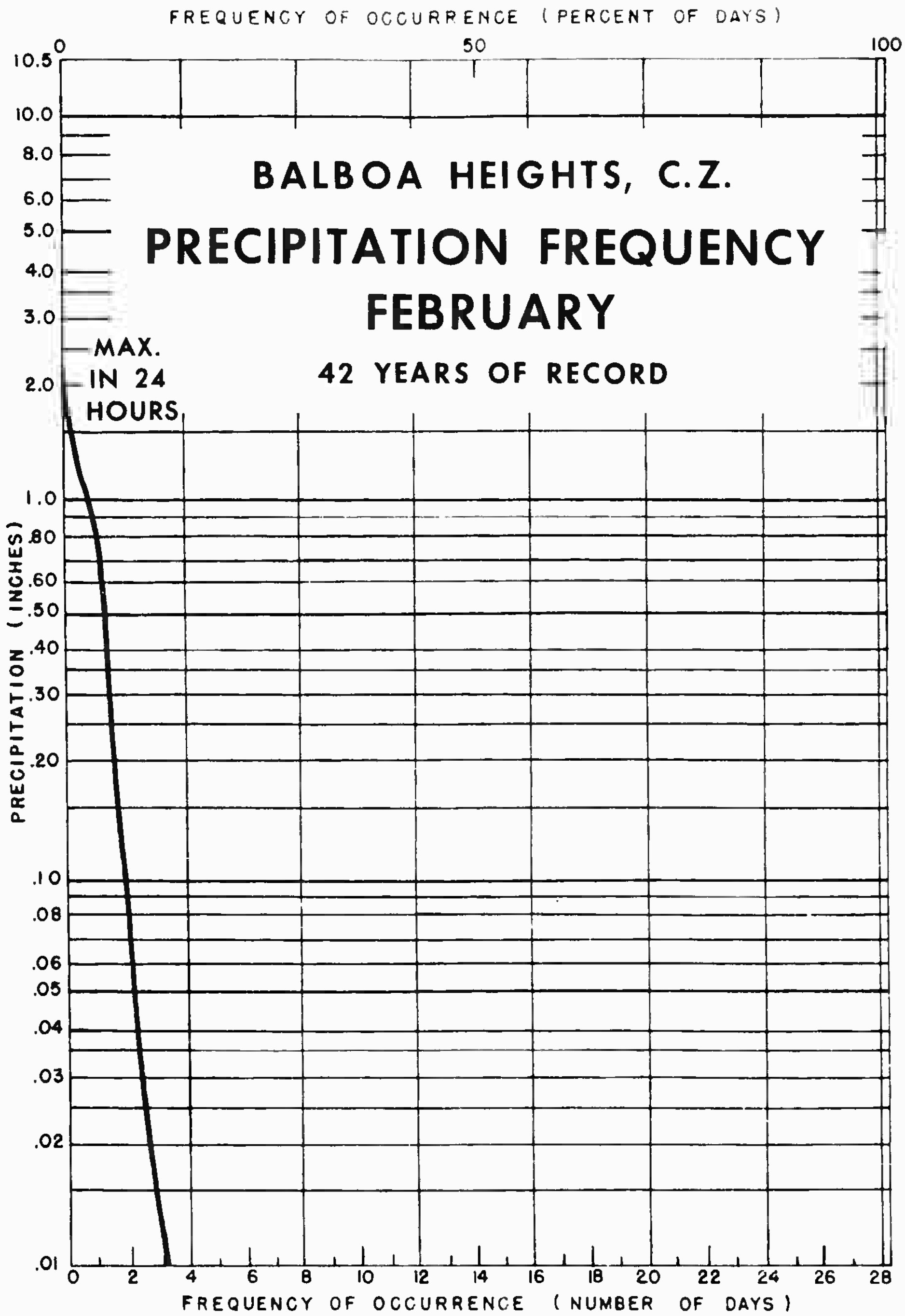
Figure 11



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 6 days during January (or approximately 20 percent of the days).

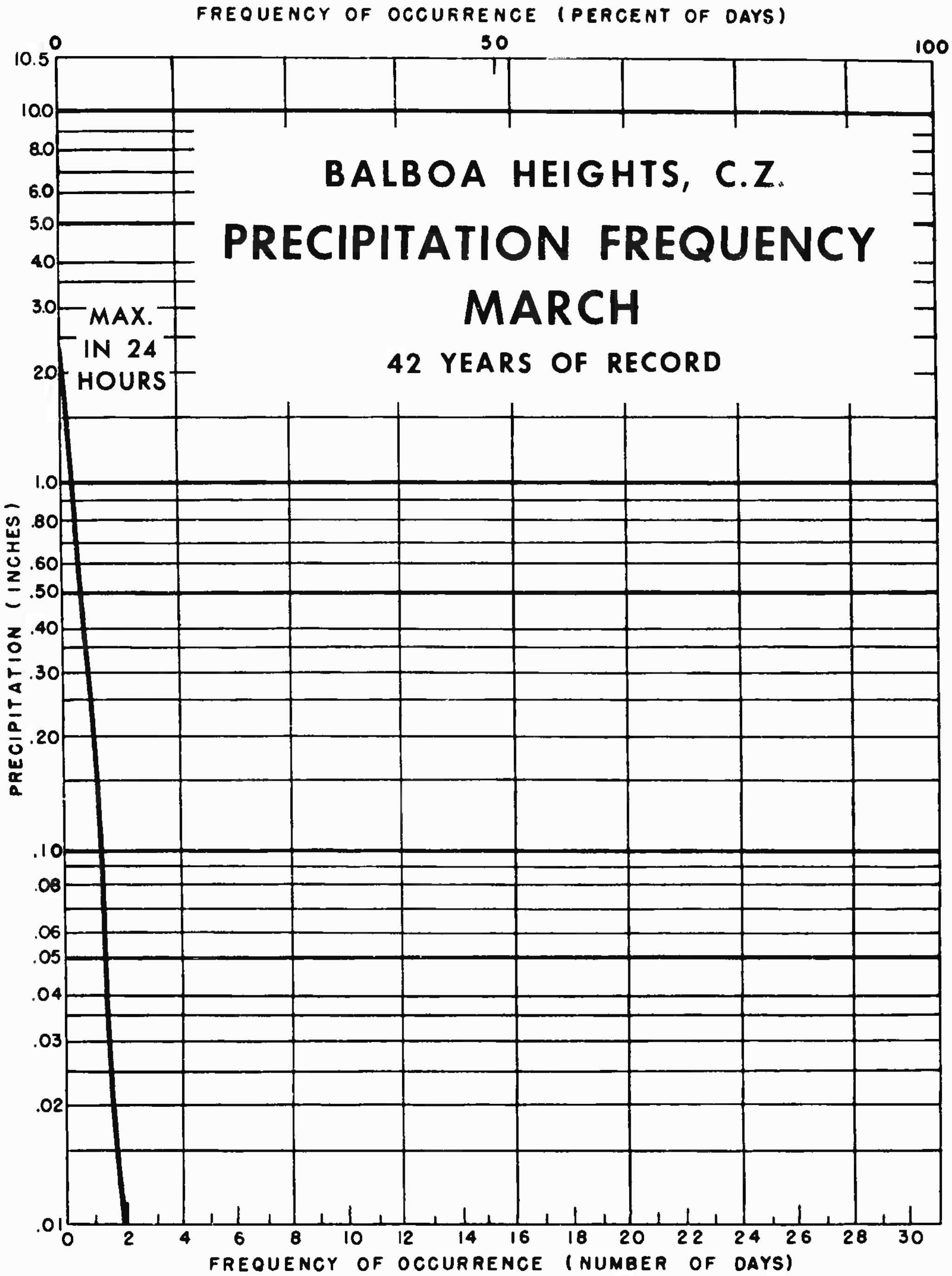
Figure 12



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 3 days during February (or approximately 10 percent of the days).

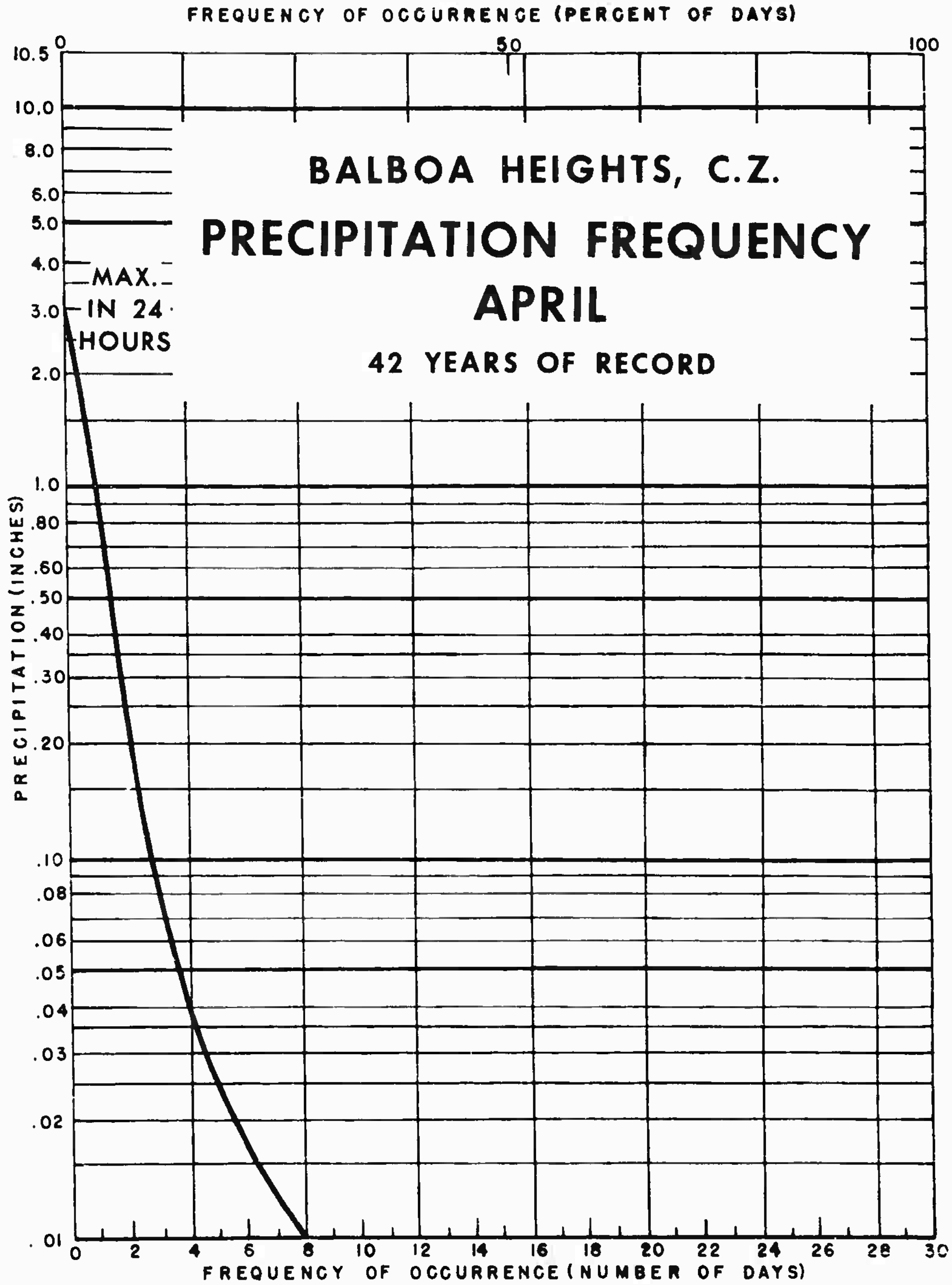
Figure 13



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 2 days during March (or approximately 5 percent of the days).

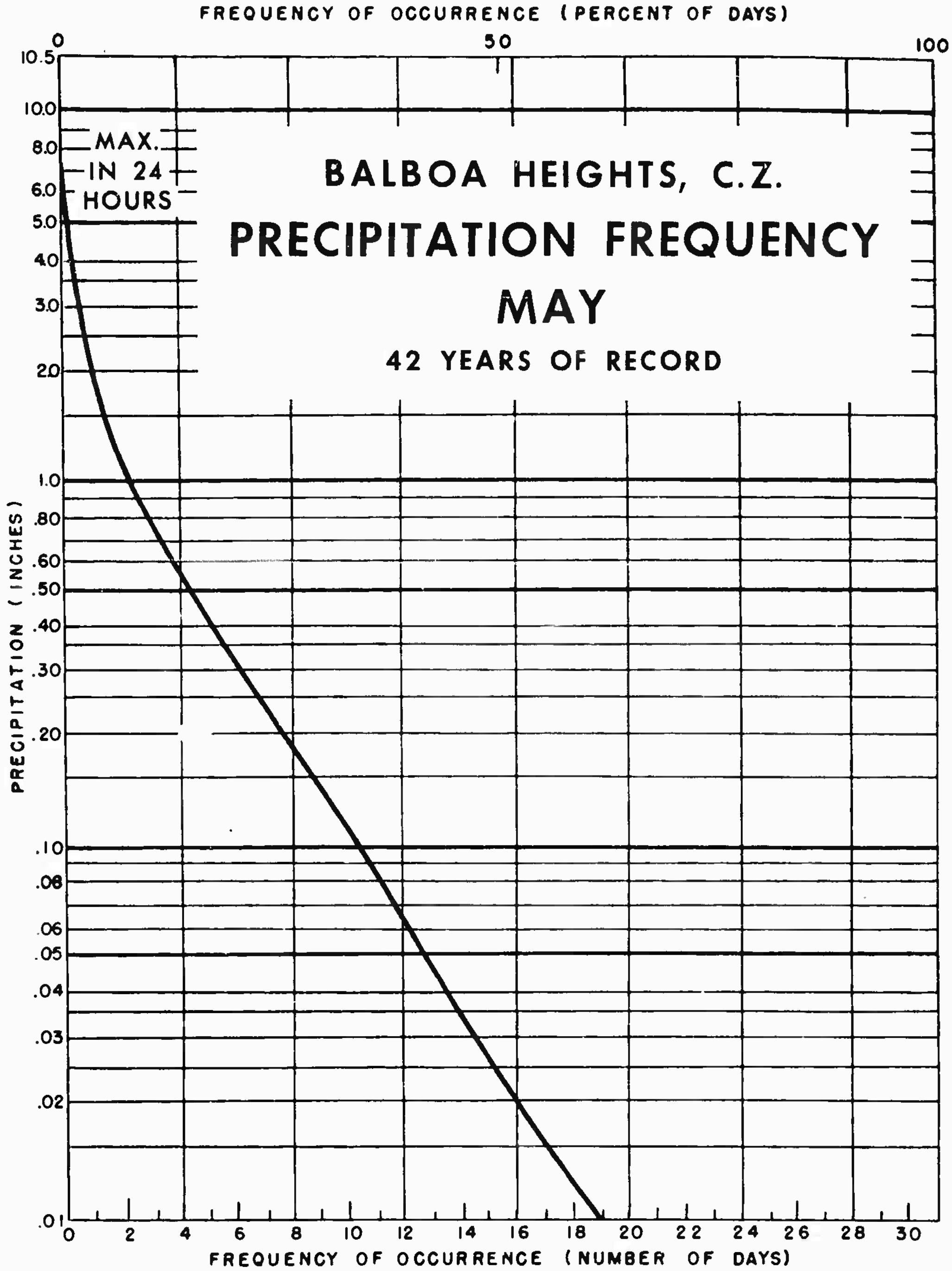
Figure 14



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 8 days during April (or approximately 26 percent of the days)

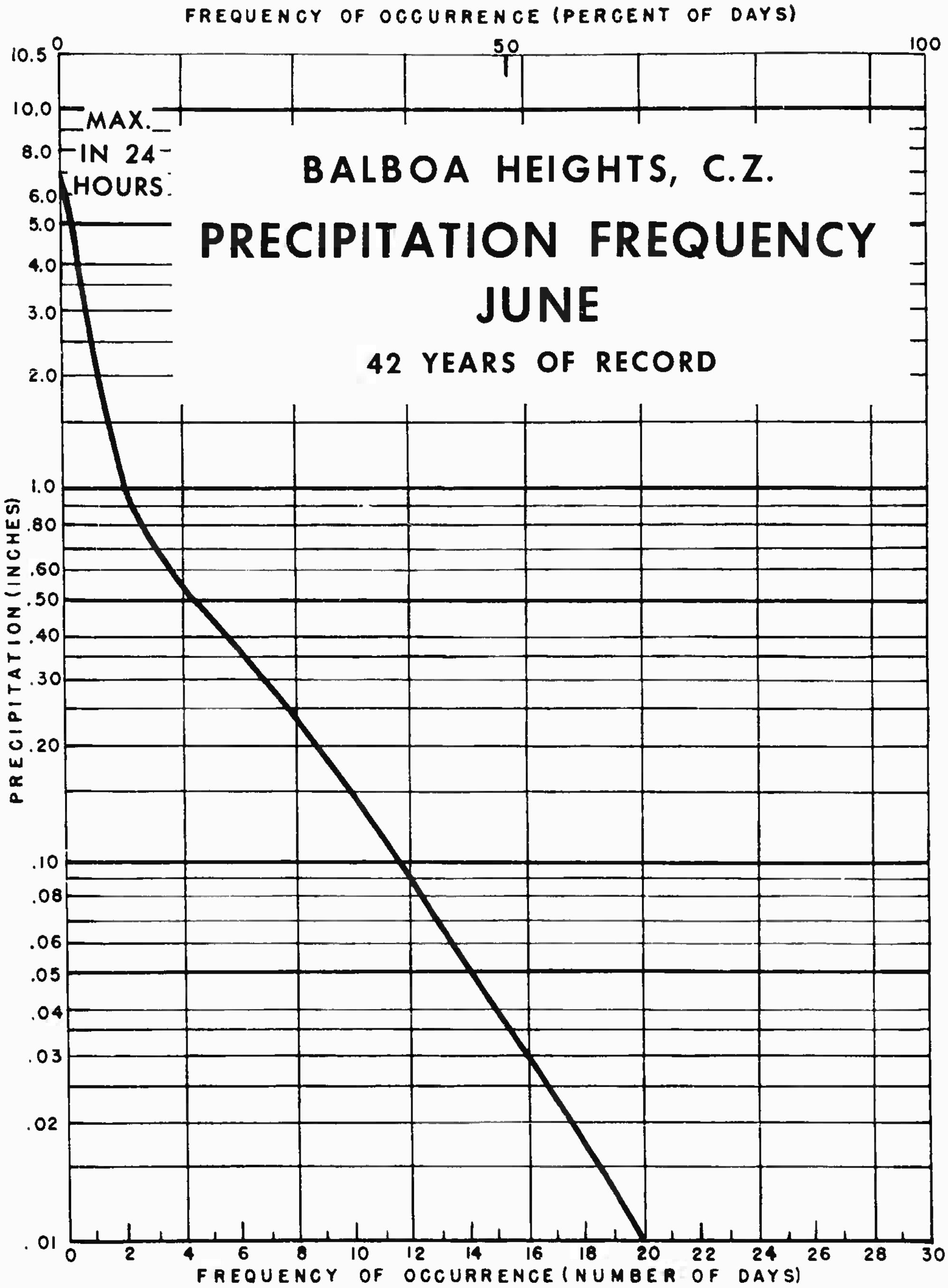
Figure 15



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 19 days during May (or approximately 62 percent of the days).

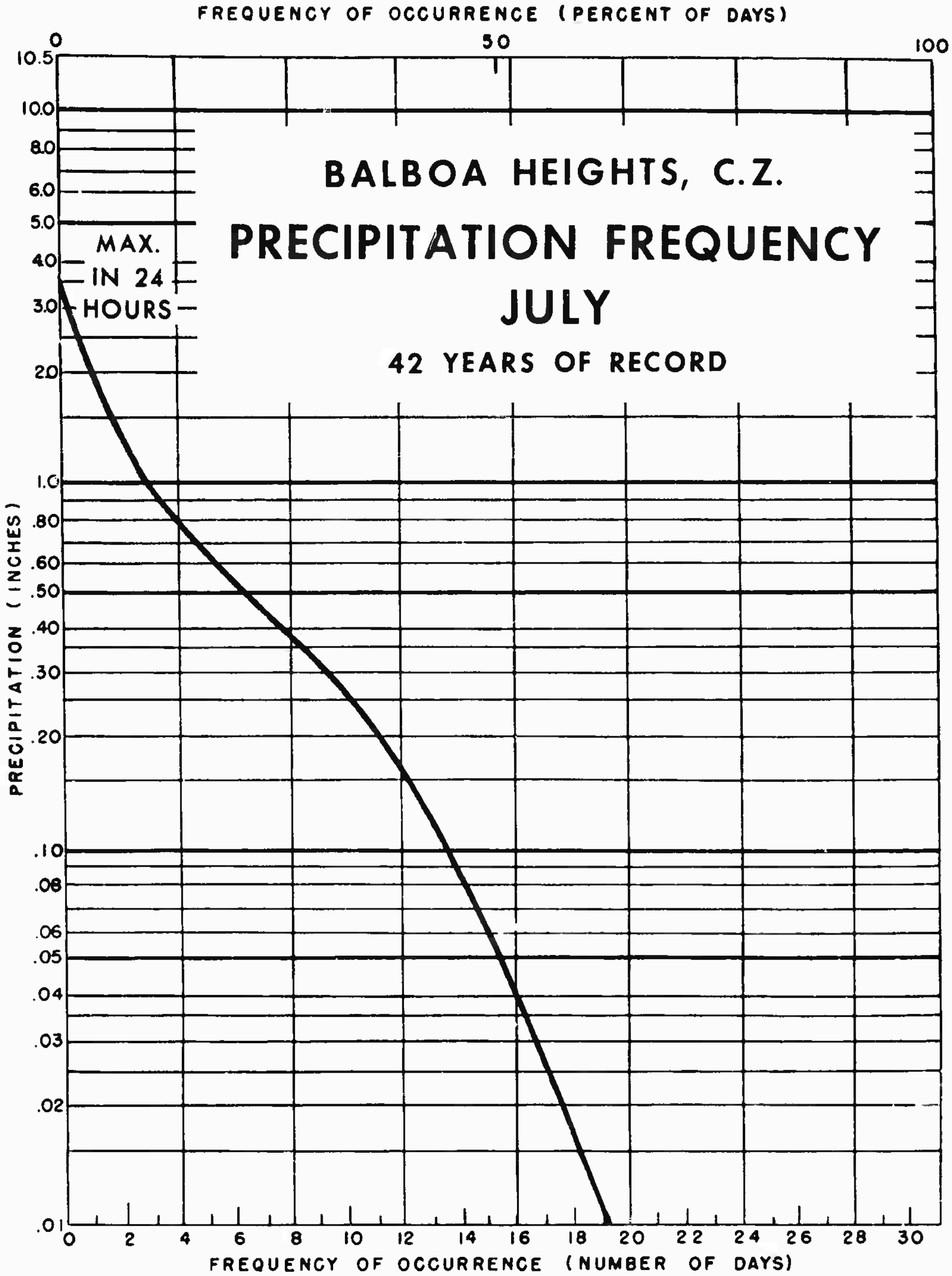
Figure 16



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 20 days during June (or approximately 65 percent of the days)

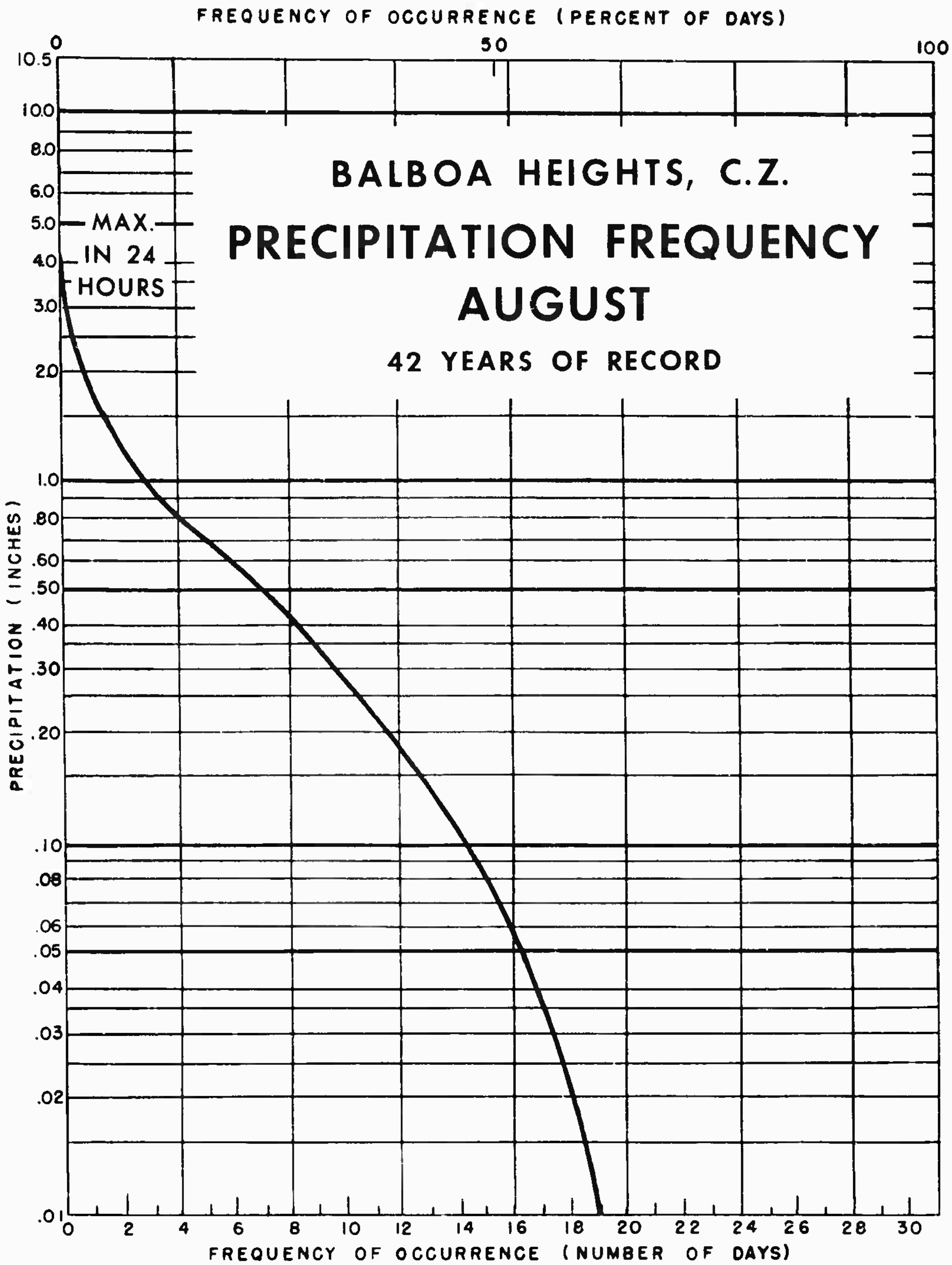
Figure 17



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 19 days during July (or approximately 60 percent of the days).

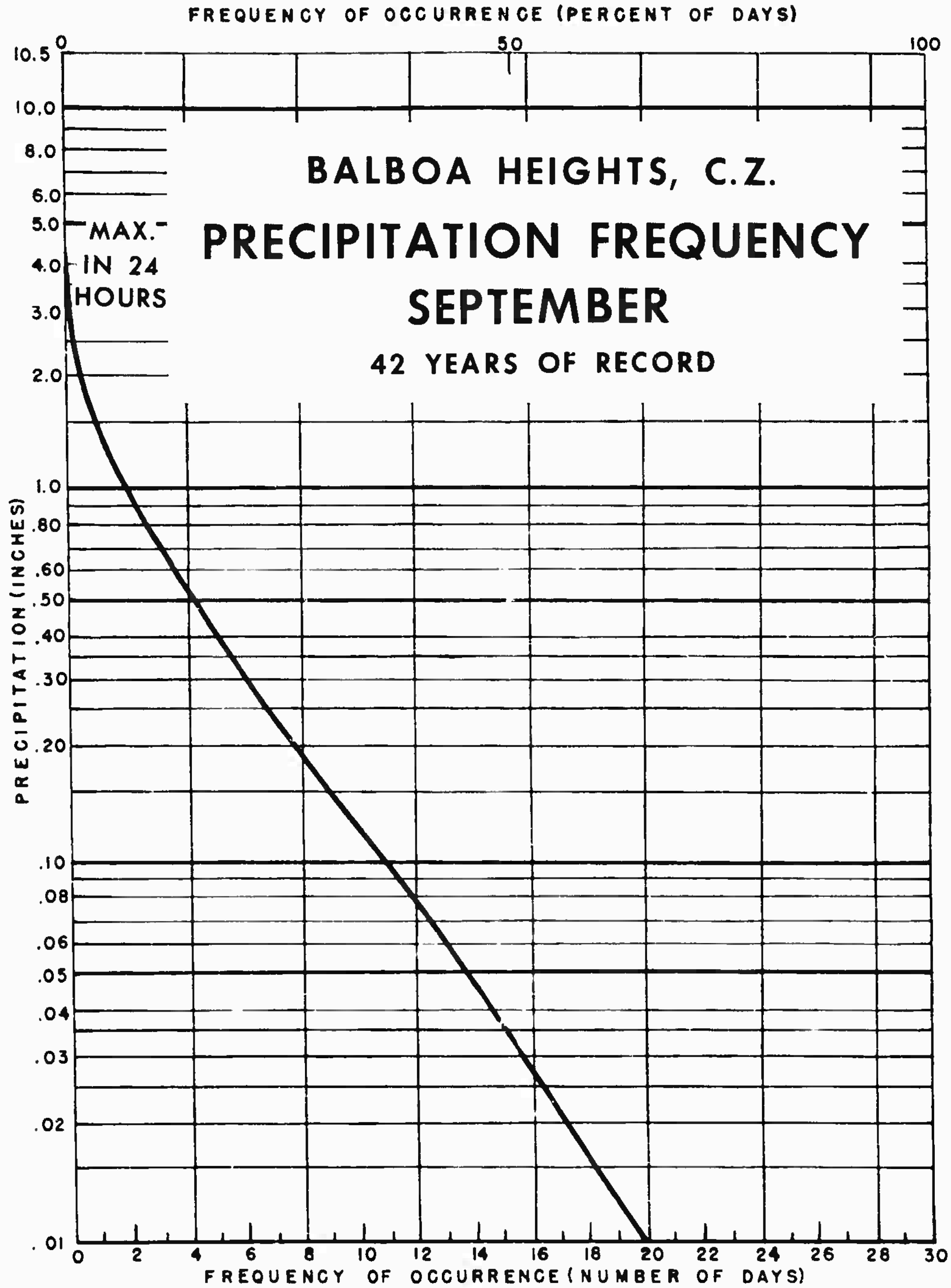
Figure 18



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 19 days during August (or approximately 60 percent of the days).

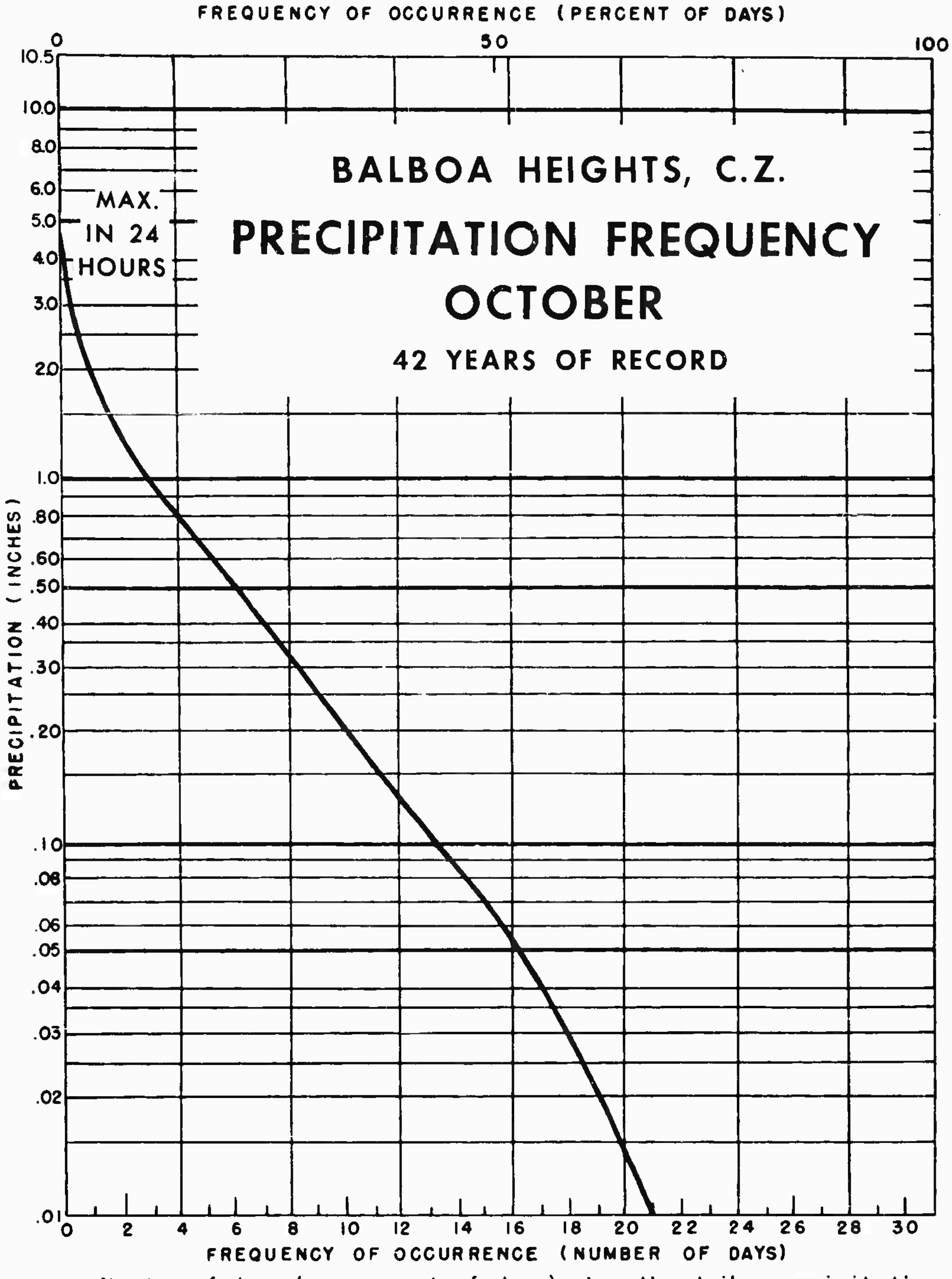
Figure 19



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 20 days during September (or approximately 66 percent of the days)

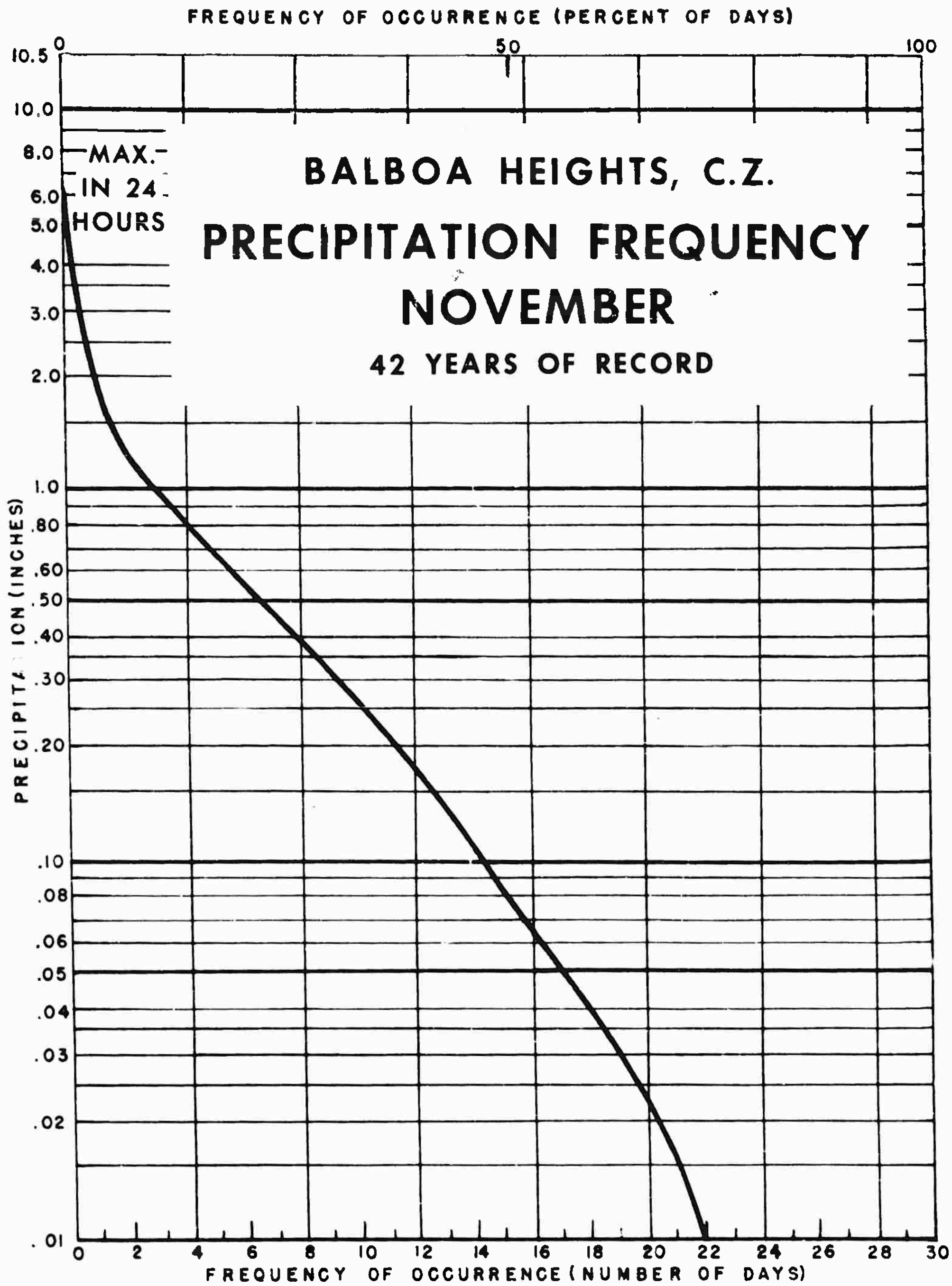
Figure 20



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 21 days during October (or approximately 68 percent of the days).

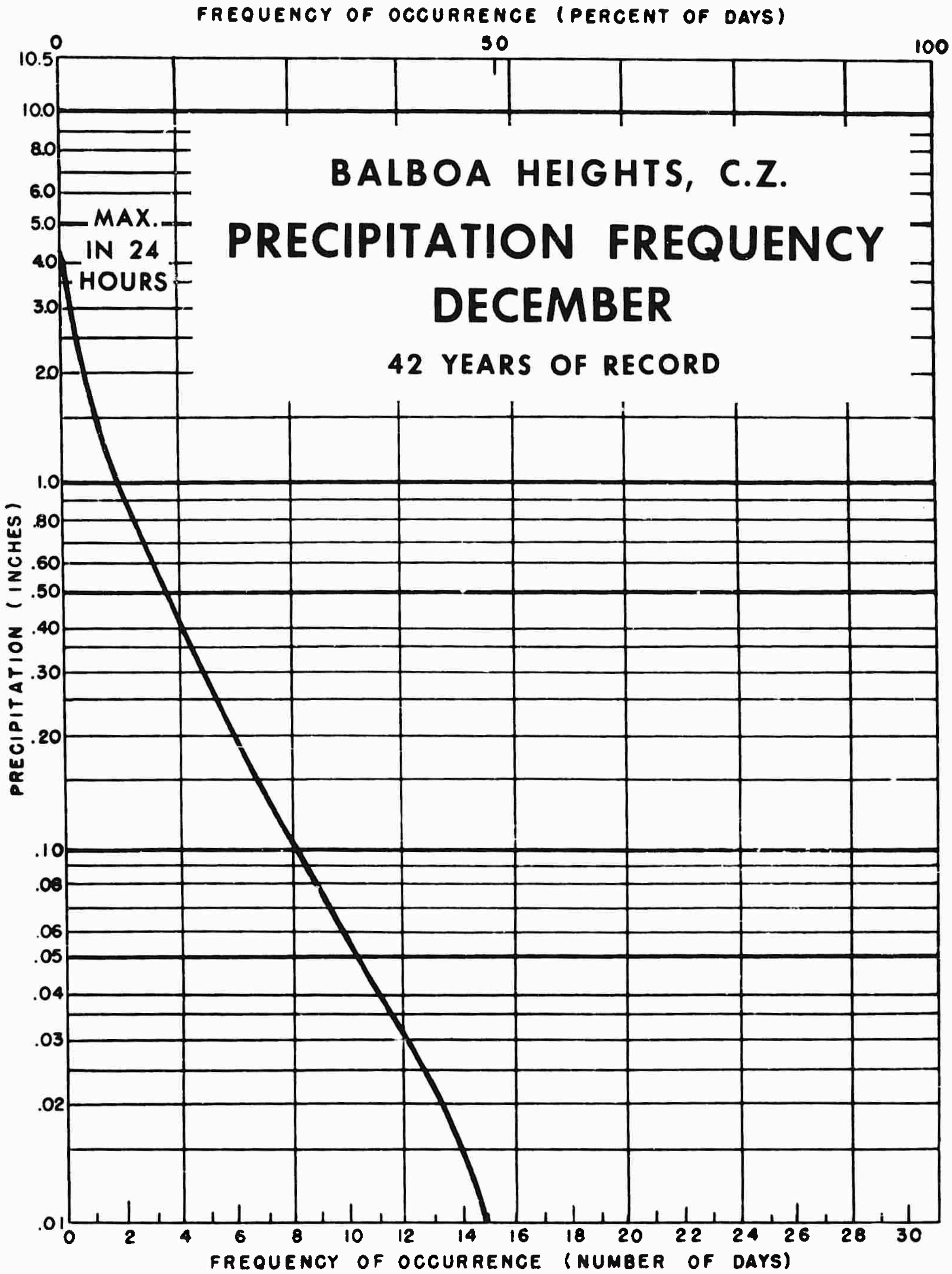
Figure 21



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 22 days during November (or approximately 72 percent of the days)

Figure 22



Number of days (or percent of days) when the daily precipitation may be expected to be the indicated amount or greater.

Example: .01 inches or more precipitation may be expected to occur 15 days during December (or approximately 47 percent of the days).

Figure 23

MEAN RELATIVE HUMIDITY
BALBOA HEIGHTS, C.Z.
LENGTH OF RECORD: 35 YEARS

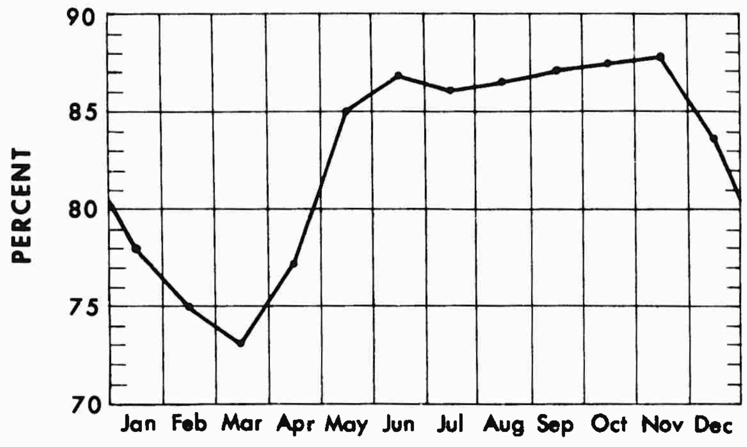


Figure - 24

MEAN DEWPOINT
BALBOA HEIGHTS, C.Z.
LENGTH OF RECORD: 35 YEARS

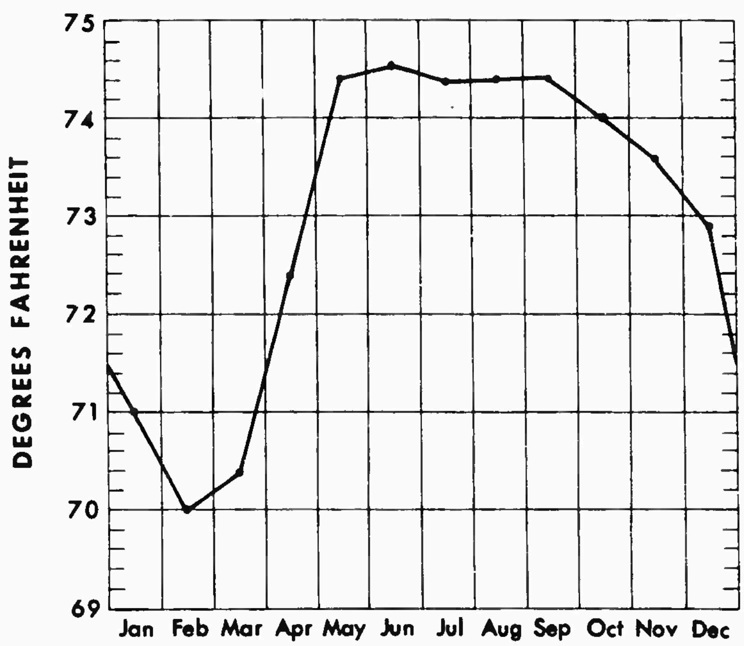
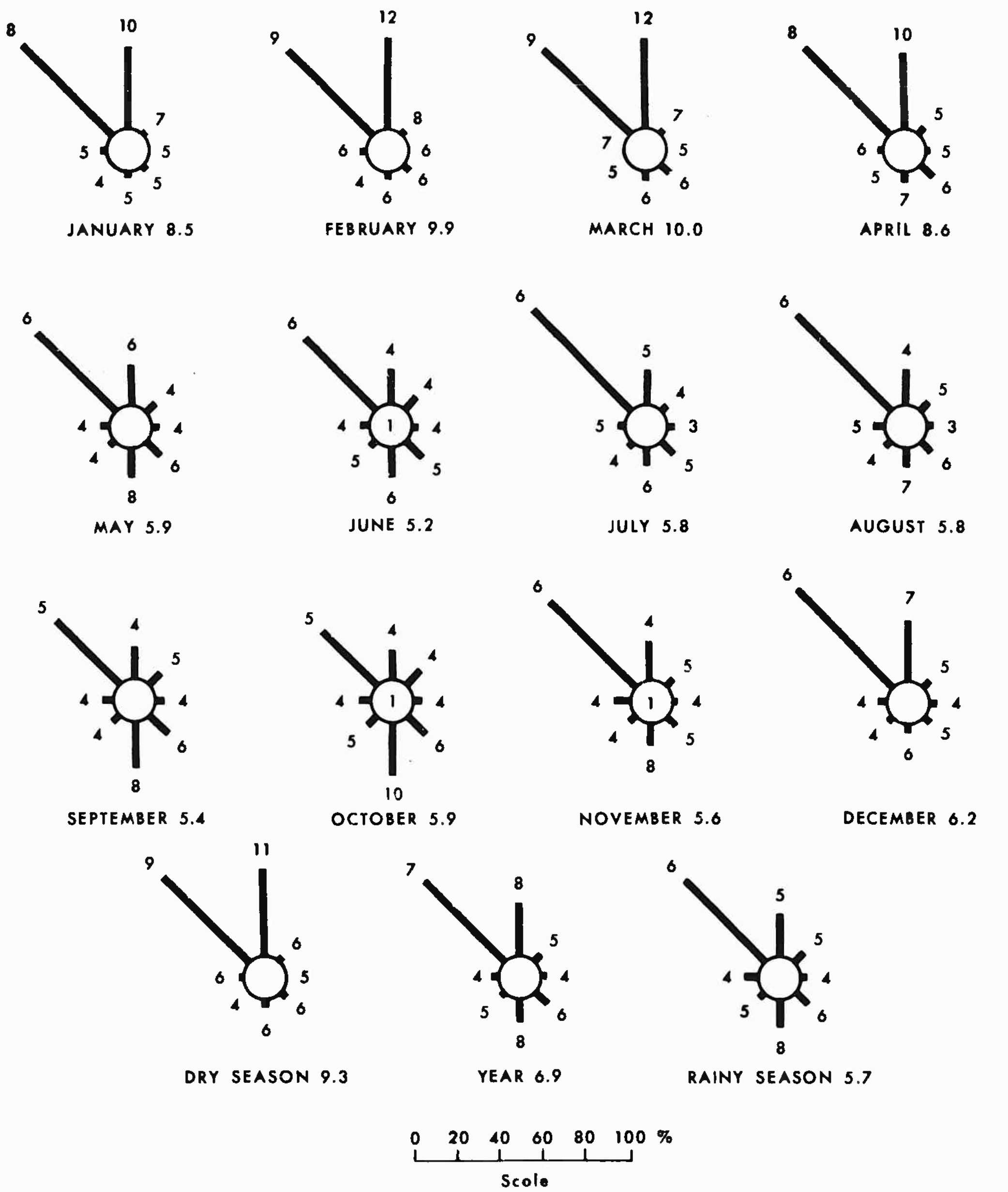


Figure - 25

WIND ROSES AT BALBOA HEIGHTS, C.Z.

35 YEARS OF RECORD 1915 - 1949



<u>Length of lines</u> from circumferences of circles represents the percentage of hours from the indicated direction. The percentage scale is shown above. The figures <u>around the circles</u> show the average velocity from that direction in miles per hour. Figure <u>in circle</u> represents percentage of hours of calm.

PL - ESD

Figure 26

FREQUENCY OF DAYS WITH THUNDERSTORMS

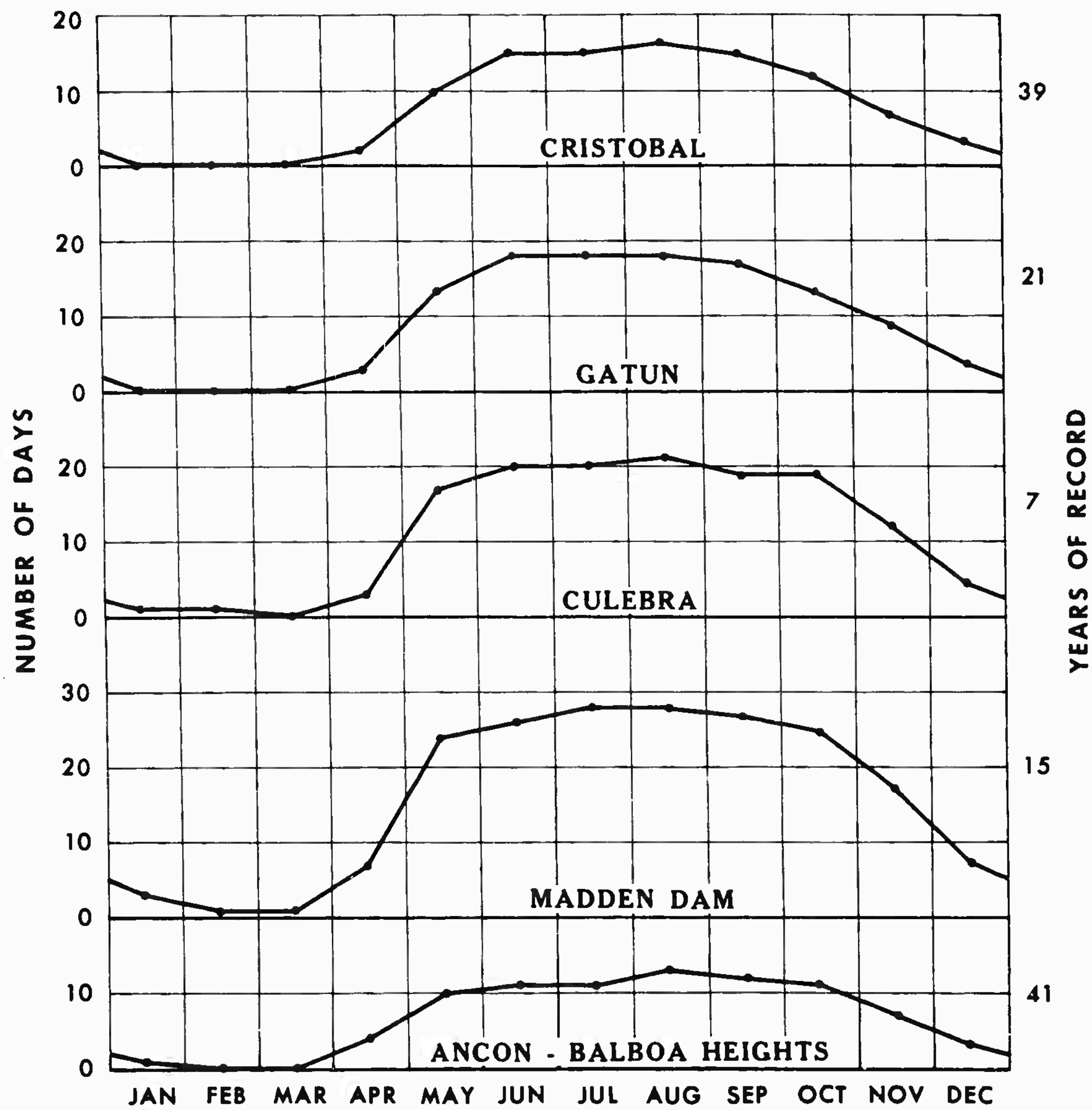


Figure 27

Appendix B

The Rio Hato Military Reservation

The Rio Hato Military Reservation is located on the southern slopes of the Cerro Iguana between Rio Farallon and Rio Majagual, both of which empty into the Gulf of Panama (see Fig. 1). Cerro Iguana (elevation 2900 feet) is one of five peaks surrounding El Valle de Anton, a remnant of the caldera of an ancient volcano, one of the chain of peaks comprising the Cordillera de Panama. On the east and south, relatively smooth-appearing slopes (the apron of the old volcanic cone) extend from these peaks to the Gulf of Panama. These slopes have been radially dissected by numerous small streams, giving a panorama of broken terrain when viewed from either east or west at Rio Hato (see Fig. 37). In a north-south direction, however, the interfluves of these streams form long corridors of gently undulating terrain.

The western border of the reservation (Rio Farallon) is approximately 1 mile east of the village of Rio Hato, and is not located on the Hato river. The Pan American Highway crosses the lower portion of the reservation, approximately 1.5 miles inland from the Gulf of Panama (see Fig. 28). North of the highway the reservation varies from 2.5 to 3 miles in width, except in the highlands above Pig Ford, where it narrows to a point at approximately 2600 ft. elevation (see Fig. 29). South of the highway the reservation is approximately 1 mile wide. The distance from the beach to Cerro Iguana is 14.5 miles.

The Pan American Highway also bisects the Rio Hato Airfield. The airfield, located in the western corridor, has a single runway 1.4 miles long with a full-length taxiway and 12 hardstands. In the dry season aircraft may park at almost any point off the runway without becoming mired down.

Terrain

The Rio Hato Military Reservation is divided by roughly parallel streams into four natural corridors. These corridors vary from 0.5 to 1 mile in width, and are approximately 9 miles in length. Each of these gently undulating strips of land is served by a road, which in most instances runs the length of the corridor.

The western corridor (Virginia Road) is bordered by the Rio Farallon and Rio Faralloncito. The west middle corridor (California Road) is bordered by Rio Faralloncito and Queb. Garrapata. The east middle corridor (Texas Road) is bordered by Queb. Garrapata and Queb. Arenilla. The eastern corridor (Ohio Road) is bordered by Queb. Arenilla and Rio Majagual. The Rio Faralloncito and Queb. Garrapata join Rio Farallon near the airfield (0.5 miles north of the Pan American Highway), and Queb. Arenilla joins Rio Majagual approximately 1.5 miles north of the Pan American Highway. The intermittent tributaries of these streams are all located within a few yards of each other on the upper slopes of Cerro Iguana. The eastern corridor is continued south to the Pan American Highway by the Rio Patino, which flows into the Gulf of Panama.

These streams, and their tributaries, carry from 1 to 3 feet of water in deeply cut trenches, though many deep pools exist. The larger streams have cut steep-sided arroyos to depths of 50 feet below the mean surface elevation of the corridor, and subsequent erosion has widened irregular gullies on either side. Because of active stream cutting, vehicular traffic within the reservation should use the established fords through these streams (Fig. 28). Rains in the highlands will result in flash flooding in one or more of these streams at any time during the year; all of the major streams may be expected to rise suddenly during the rainy season.

Vegetation

The reservation is an ancient clearing that has been maintained as a pasture by annual burning (as is done in most of the fields in the area between Chorrera and Pentonome). Many trees survive the annual burning. Many of the species of trees found in the reservation are the same as those in other wet-and-dry forests on the Pacific-facing slopes of Panama. In most instances these trees are found in clumps in the deeply cut stream beds. The interfluve areas are largely bare of trees, supporting only grasses and scattered clumps of bushes (see Fig. 30).

The dwarfed and stunted xerophilous trees that are scattered throughout the Rio Hato area include the "chumigo", *Curatella americana*; the "moranon", *Anacardium occidentale*; and the "nance", *Byrsonima crassifolia*. Growing among the grasses and sedges (in subirrigated areas) are many herbaceous flowering plants, some of them minute, which are not observed elsewhere in Panama except in other savanna-like areas.

Ant trees, *Cecropia* spp., and balsa, *Ochroma Lagopus*, are weed trees that appear in each new clearing, as does the yellow "legume", *Crassia* sp. Where not cleared, lowland vegetation throughout the Pacific-facing slopes of Panama is dominated by deciduous "cuipos", *Cavanillesia platanifolia*; "espinosos", *Bombax quinatum*; and "espaves", *Anacardium excelsum*. These trees are found in remnant forests in the savanna-like areas, such as Rio Hato, El Valle, and Cerro Campana. The annual burning in the clearings has permitted the introduction of new species of vegetation which would not have flourished under forest conditions.

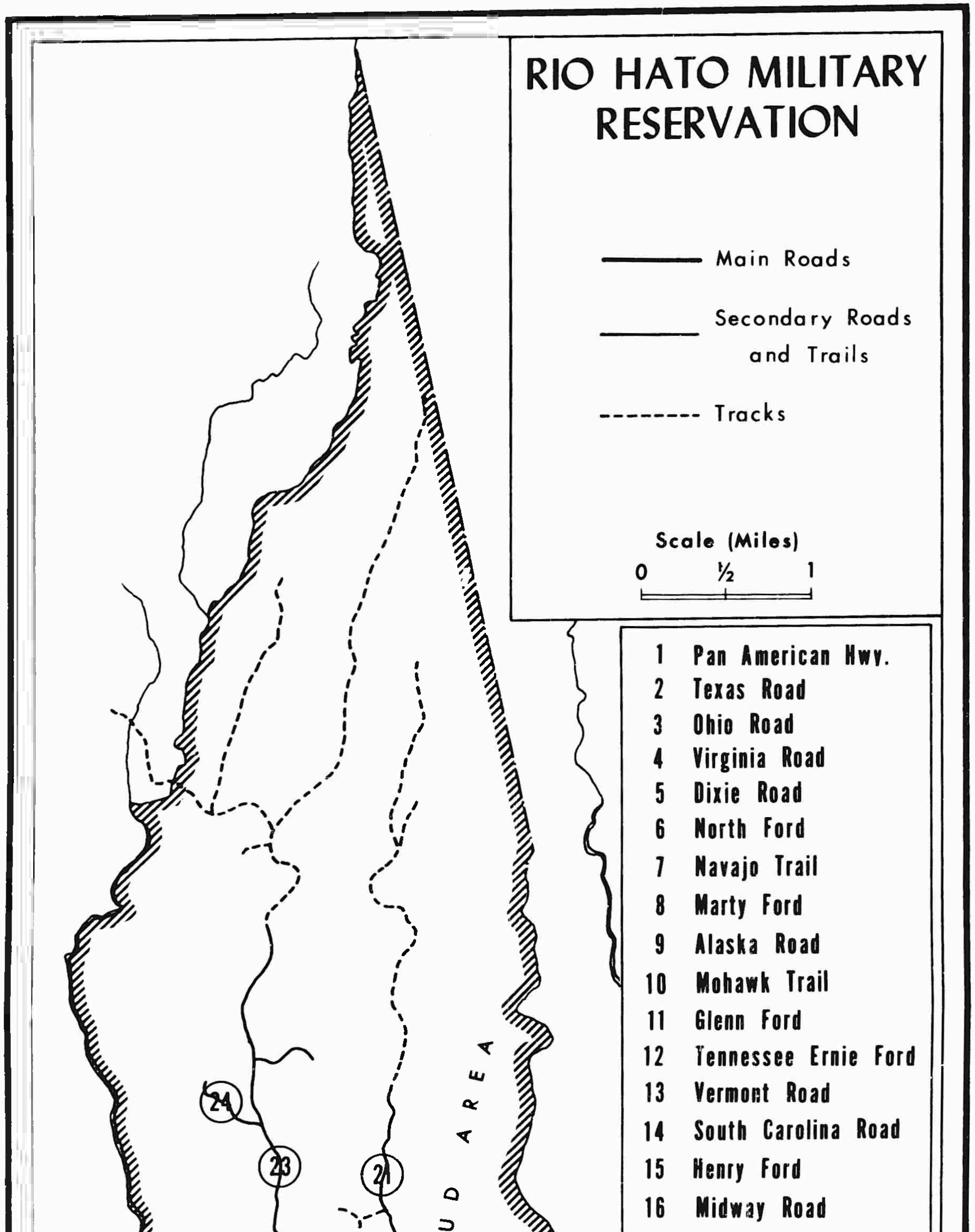
Climate

Temperatures at Rio Hato are similar to those reported at Balboa Heights. Mean monthly temperatures at Rio Hato are only slightly higher

(1 to 2F°) than the values reported for Balboa Heights. Although 97°F is the highest temperature ever observed at the two stations, this maximum has occurred during each of seven months (January, February, March, April, July, November, December) at Rio Hato, while it has occurred only once (April) at Balboa Heights. The lowest temperatures observed at Rio Hato (66°F) are also slightly higher than those at Balboa Heights (63°F). However, at both stations the lowest minimum reported at the onset of the rainy season is 70°F (see Tables II and VII).

The greatest climatic difference between the two stations is in precipitation. Rio Hato is in a rain shadow due to its location on the leeward side of Cerro Iguana and the peaks surrounding El Valle de Anton. Extreme annual rainfall amounts at Rio Hato approximate the annual average amount at Balboa Heights (70.3 inches) (Tables III and VIII). The dry season (December through April) at Rio Hato is slightly longer than at Balboa Heights, and much drier. At Rio Hato during the average dry season less than 1 inch of rain falls, whereas over 5 inches fall at Balboa Heights. In some years only a trace of rain has been recorded at either station during the dry season, but the greatest dry season rainfall at Rio Hato is less than the average amount received during this period at Balboa Heights. The rainy season at Rio Hato is usually characterized by two periods of relatively intense rainfall (May-July and October-November), when 4 to 8 inches of rain may be expected each month. During each of these 5 months from 10 to 15 inches of rain has fallen at Rio Hato. A so-called "little dry season" usually occurs in August or September, a period of 2 or 3 weeks with little or no rain. At any time during the average rainy season at Rio Hato, periods of 10 days without rain are common. While roads may contain pools of standing water or mud, slightly higher stretches may be dusty even during the month of greatest rainfall (October).

High relative humidities (over 90 per cent) are reported in the early morning and late evening hours from June to December at Rio Hato, from May to January at Balboa Heights. However, afternoon relative humidities are lower at Rio Hato than at Balboa Heights only in January, February, and November. These differences are only 1 to 3 per cent and indicate a close agreement in humidity conditions between the two stations. Greater differences would be expected due to the marked differences in rainfall. One causal factor in the high afternoon humidities at Rio Hato is on-shore wind from the Gulf of Panama where water temperatures are usually within 2F° of air temperatures.


RIO HATO MILITARY RESERVATION
Main Roads
Secondary Roads and Trails
Tracks
Scale (Miles)
0 ½ 1
1 Pan American Hwy.
2 Texas Road
3 Ohio Road
4 Virginia Road
5 Dixie Road
6 North Ford
7 Navajo Trail
8 Marty Ford
9 Alaska Road
10 Mohawk Trail
11 Glenn Ford
12 Tennessee Ernie Ford
13 Vermont Road
14 South Carolina Road
15 Henry Ford
16 Midway Road
24
23
21
U D AREA

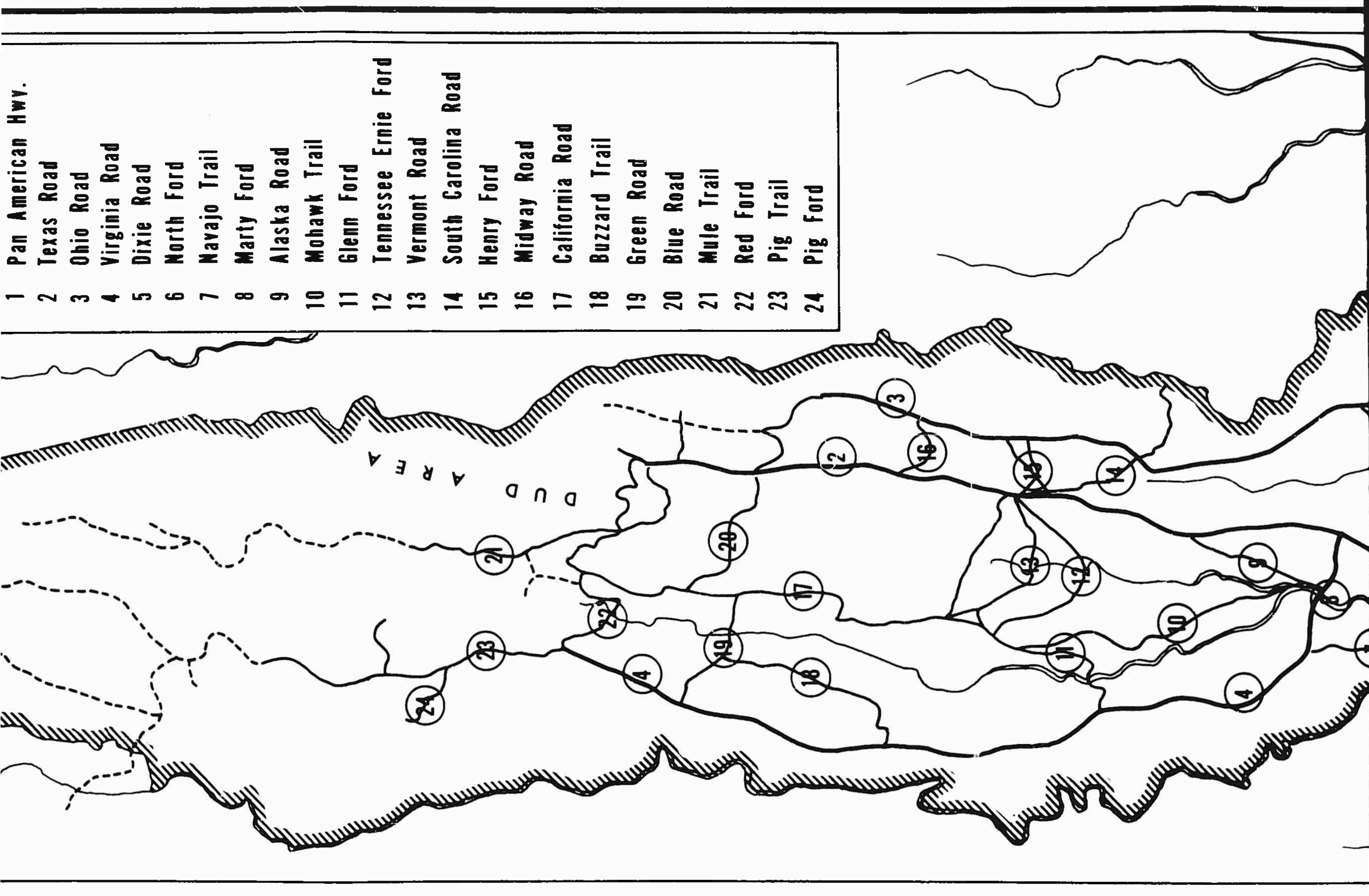
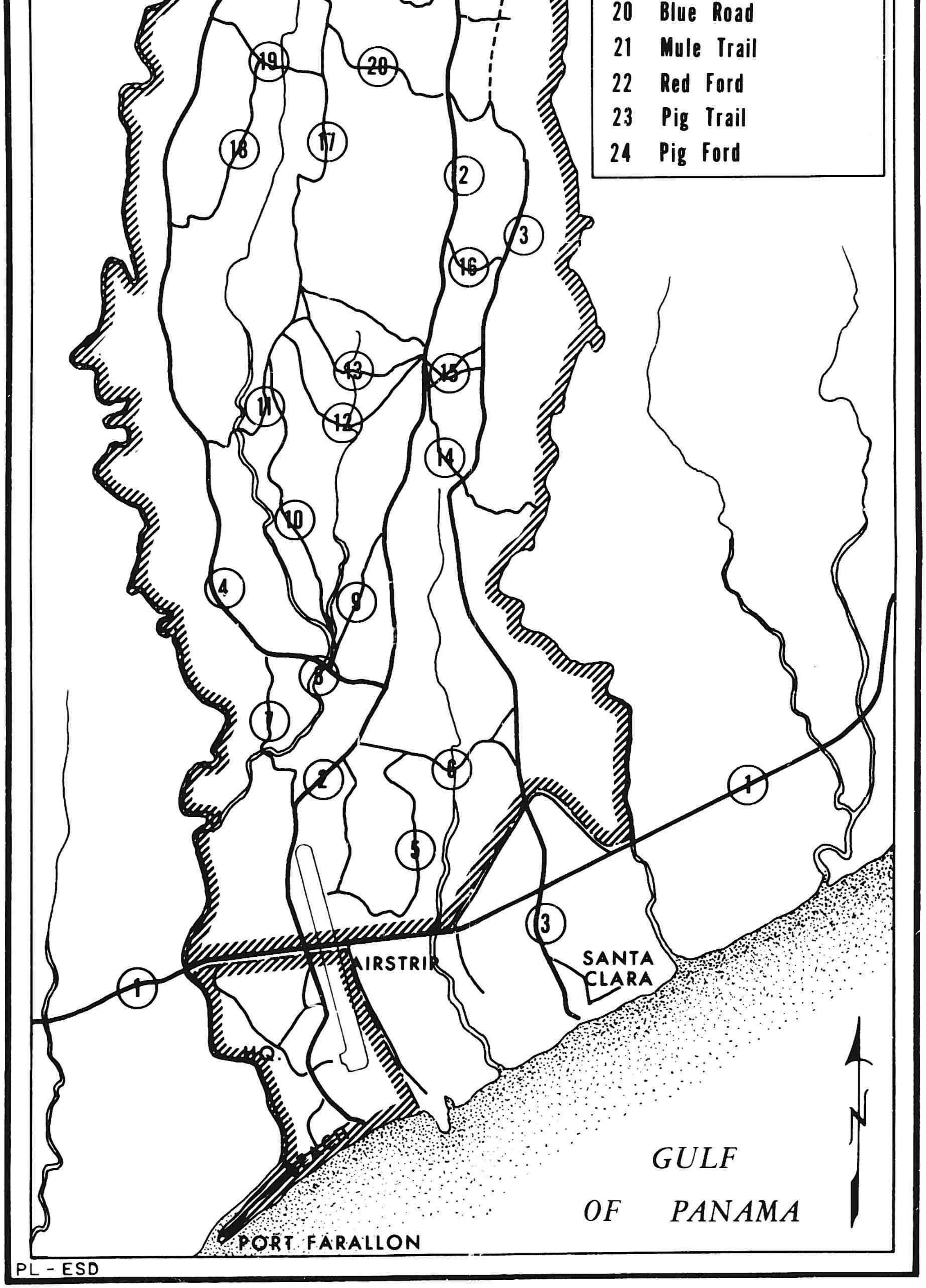
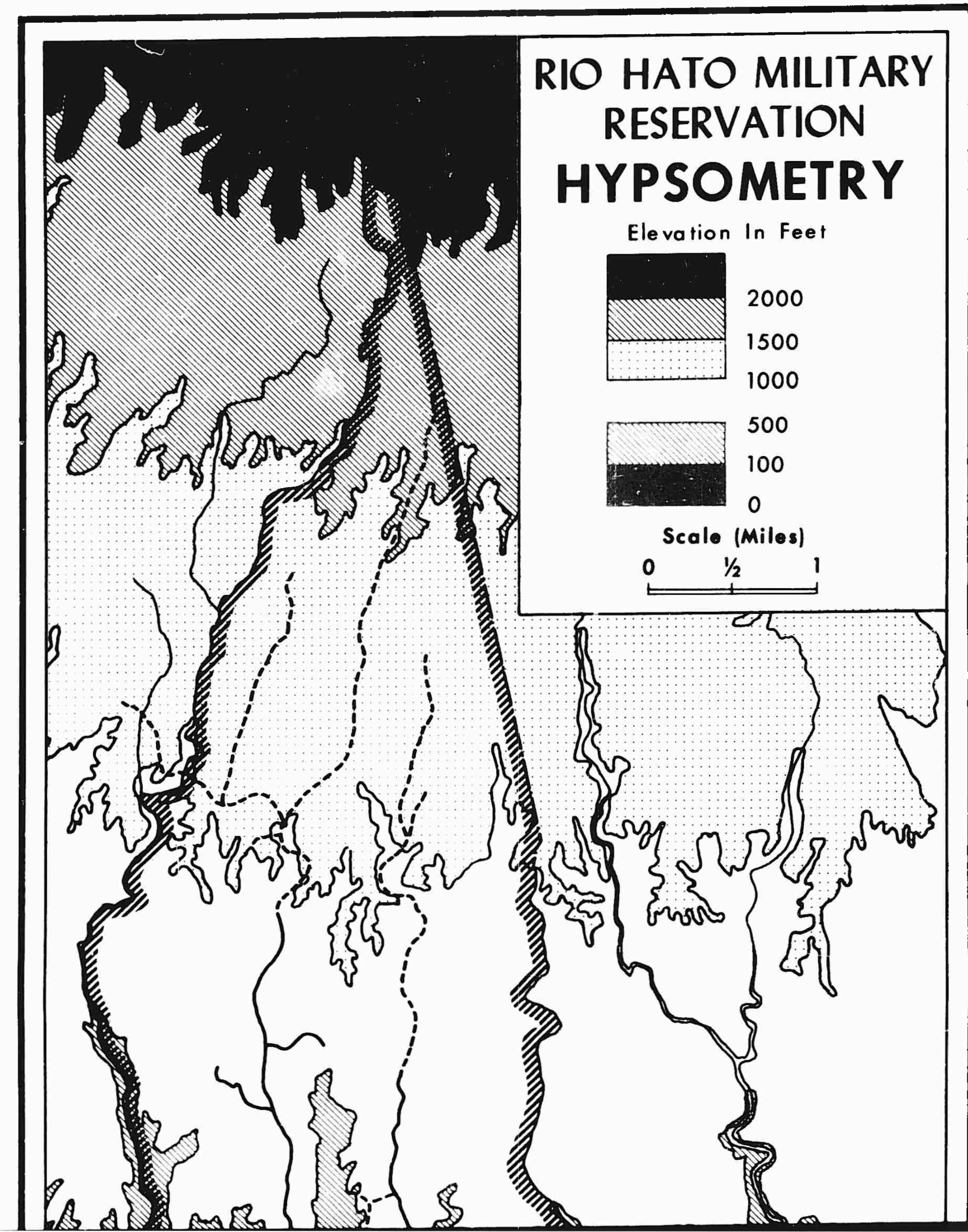

1 Pan American Hwy.
2 Texas Road
3 Ohio Road
4 Virginia Road
5 Dixie Road
6 North Ford
7 Navajo Trail
8 Marty Ford
9 Alaska Road
10 Mohawk Trail
11 Glenn Ford
12 Tennessee Ernie Ford
13 Vermont Road
14 South Carolina Road
15 Henry Ford
16 Midway Road
17 California Road
18 Buzzard Trail
19 Green Road
20 Blue Road
21 Mule Trail
22 Red Ford
23 Pig Trail
24 Pig Ford
DUD AREA

Figure 28

2


20 Blue Road
21 Mule Trail
22 Red Ford
23 Pig Trail
24 Pig Ford
AIRSTRIP
SANTA CLARA
H.Q.
PORT FARALLON
GULF OF PANAMA
PL - ESD

re 28
52


RIO HATO MILITARY RESERVATION
HYPSOMETRY
Elevation In Feet
2000
1500
1000
500
100
0
Scale (Miles)
0
½
1

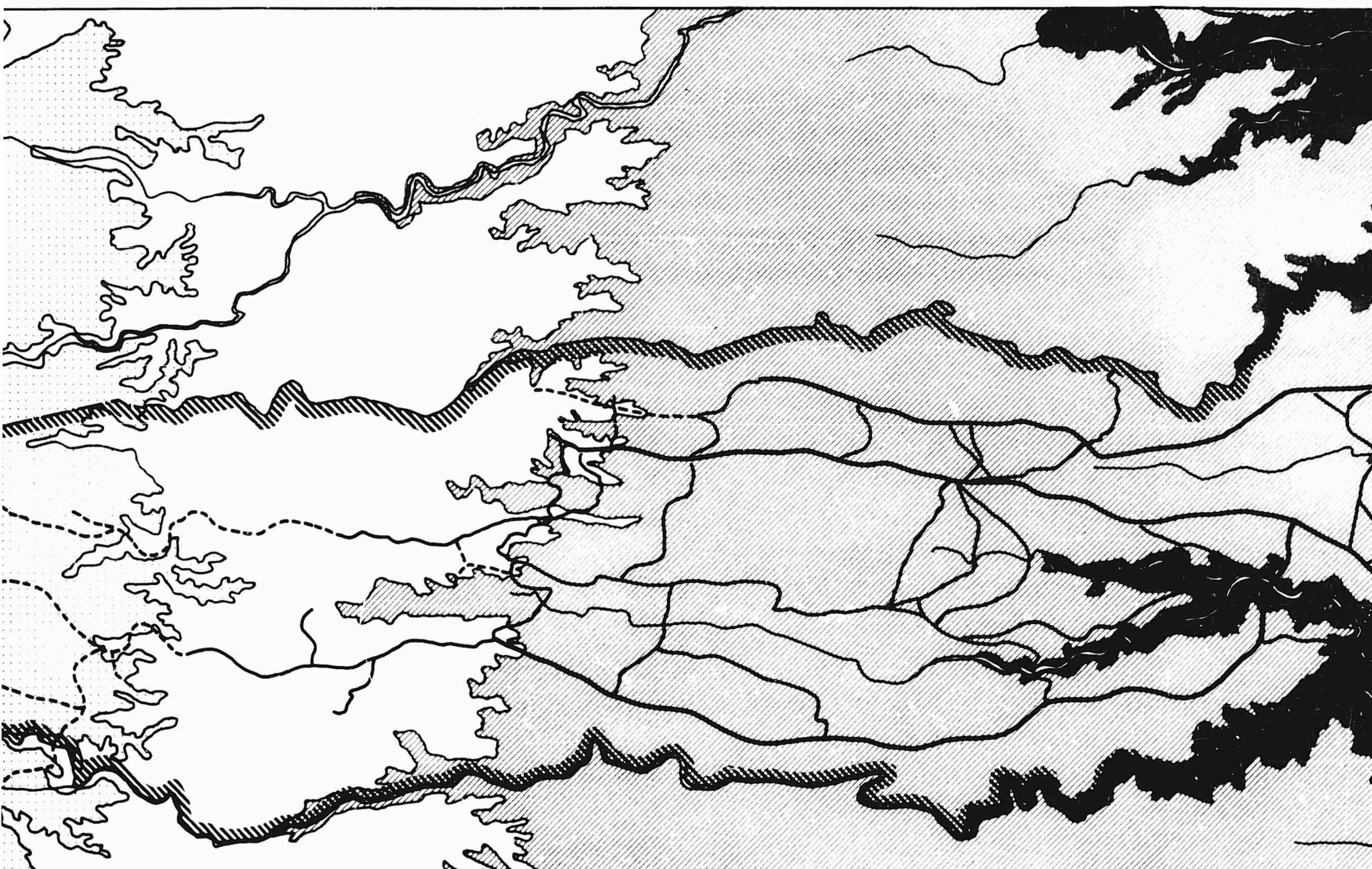
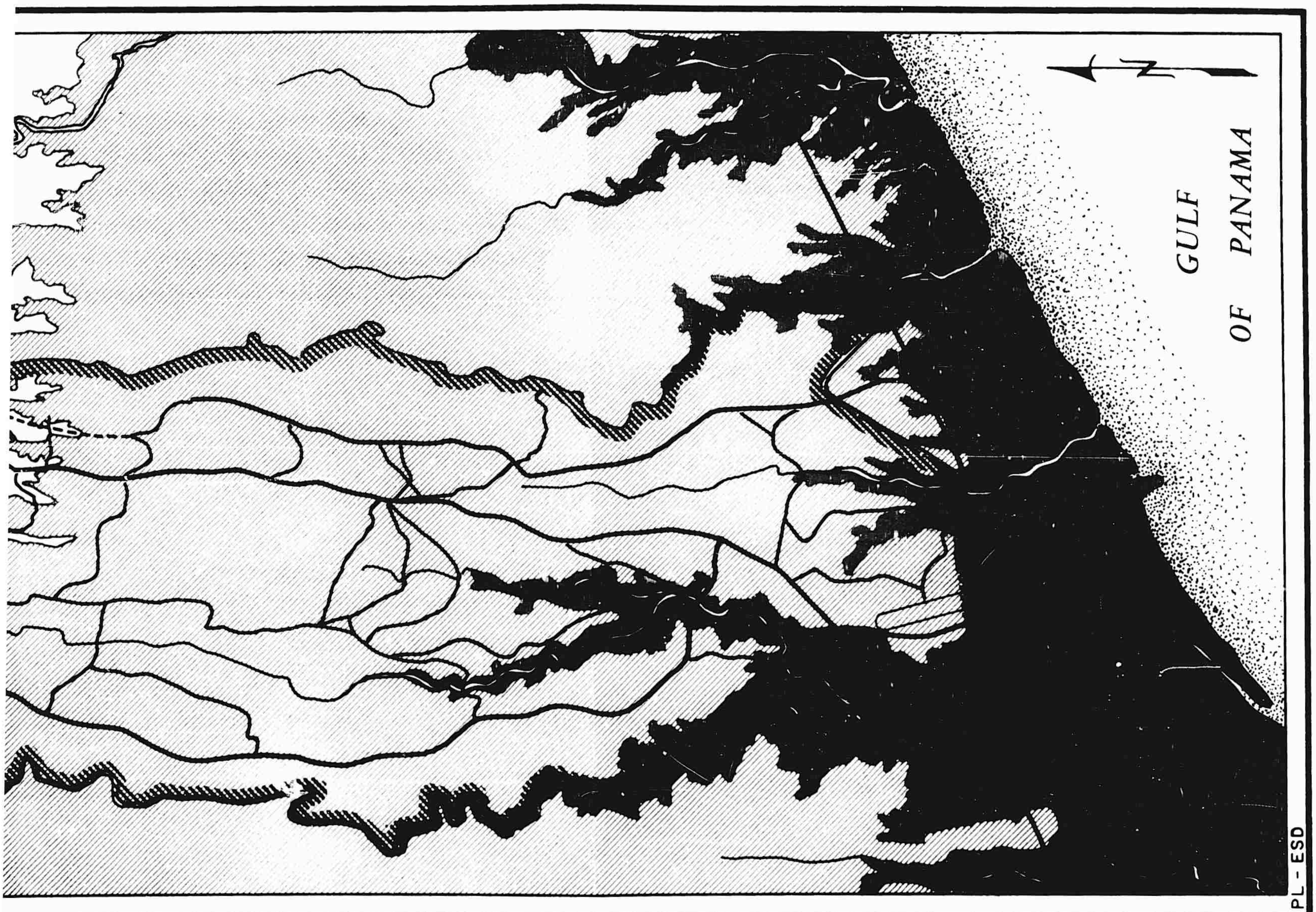


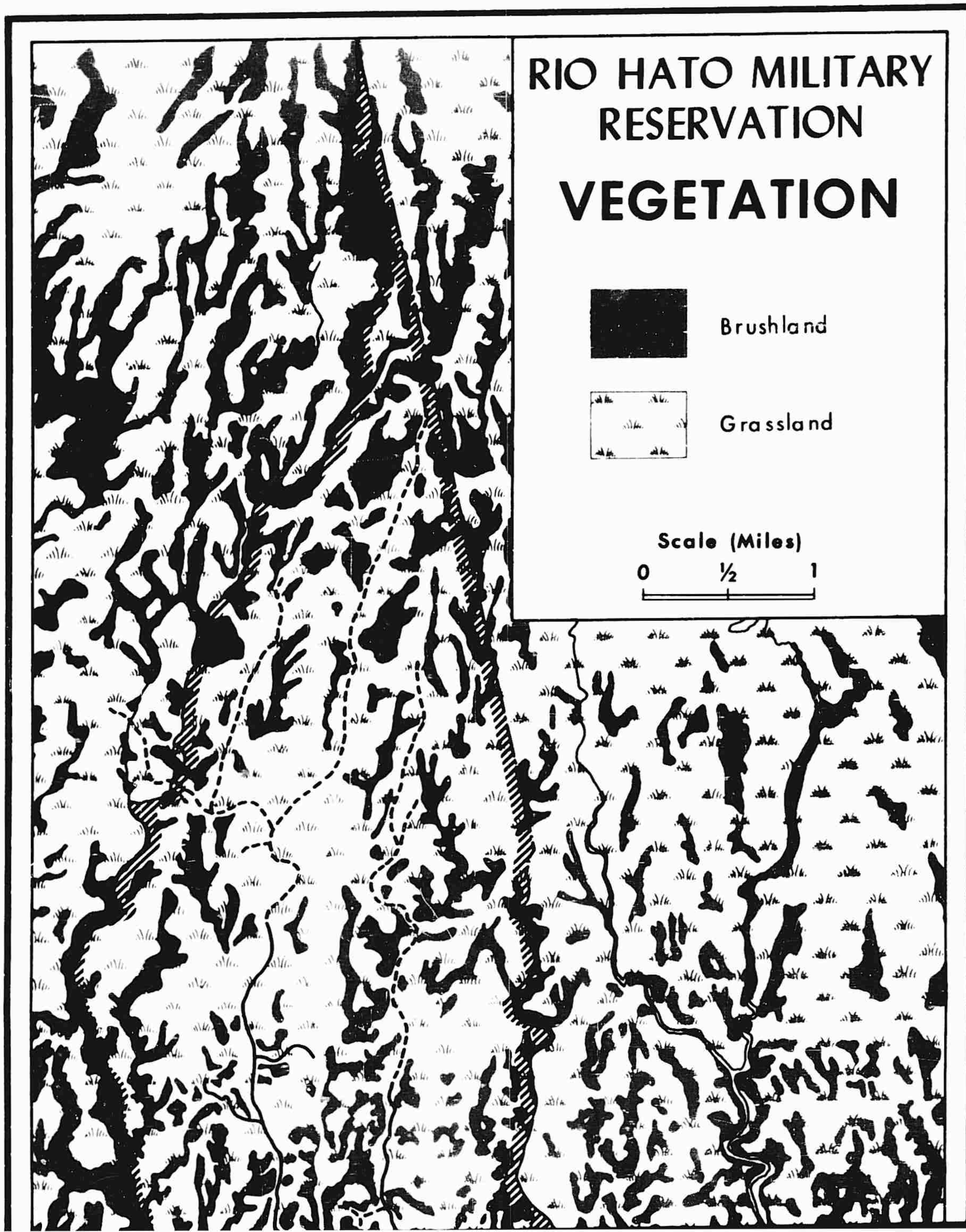
Figure 29
53

2



.gure 29

3


RIO HATO MILITARY
RESERVATION
VEGETATION
Brushland
Grassland
Scale (Miles)
0
½
1

1

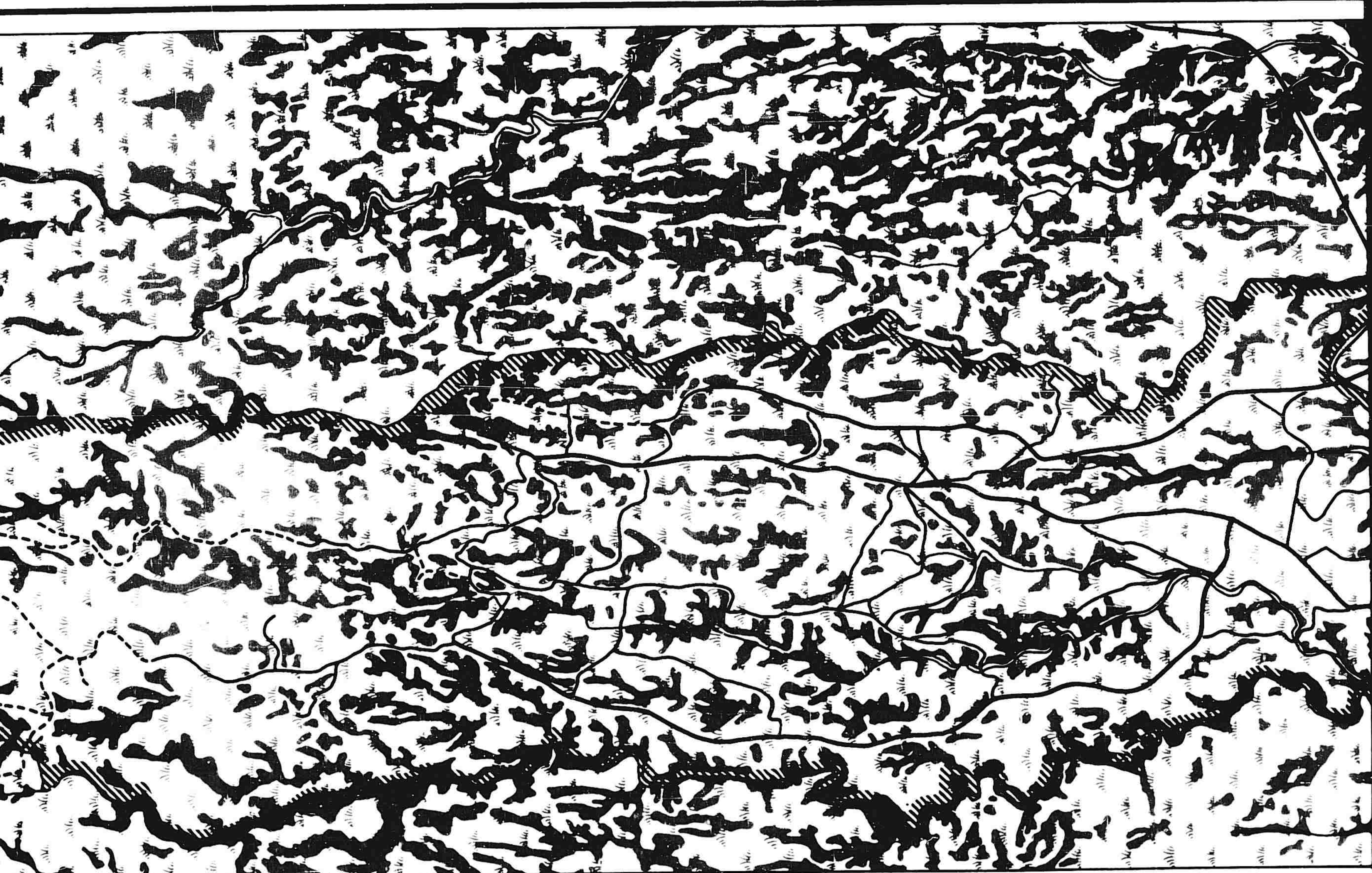
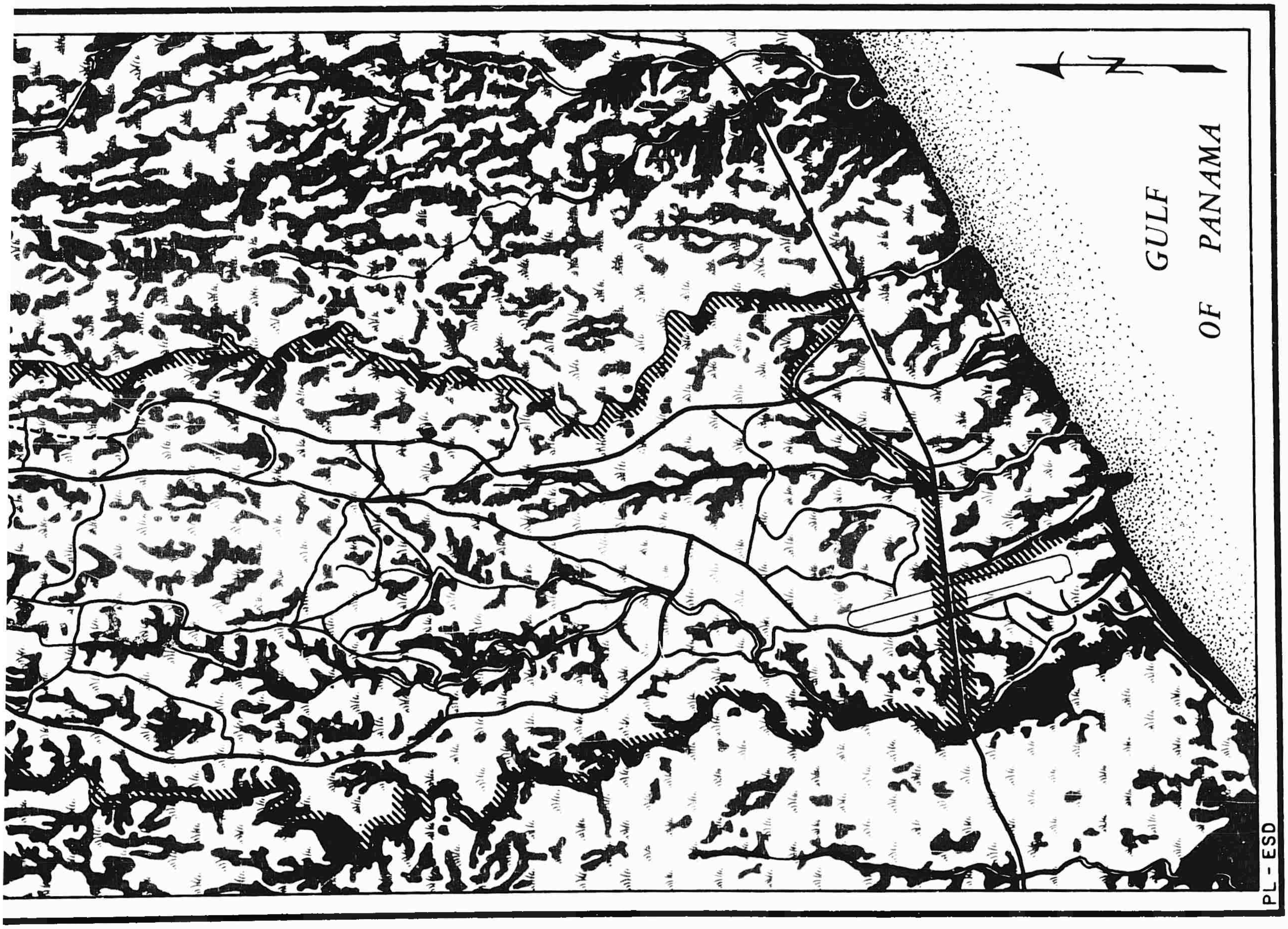


Figure 30

2



ure 30
54

3

TABLE VII. TEMPERATURE (°F)

RIO HATO MILITARY RESERVATION AIRFIELD, R. P.*

Month	Mean	Mean Daily Max.	Mean Daily Min.	Ab. Max.	Ab. Min.
Jan	81	90	72	97	66
Feb	82	90	74	97	68
Mar	83	91	74	97	66
Apr	83	91	75	97	68
May	81	88	74	95	70
Jun	80	87	73	95	68
Jul	80	87	74	97	66
Aug	80	87	73	95	66
Sep	80	87	73	93	68
Oct	79	86	72	93	68
Nov	80	87	73	97	66
Dec	80	88	72	97	66
Year	81	88	73	97	66

*Length of Record: 4 years (to 1947).

TABLE VIII. PRECIPITATION (IN.)

RIO HATO MILITARY RESERVATION AIRFIELD, R. P.*

Month	Mean	Maximum	Minimum	Days with Rain	Days with Thunderstorms
Jan	0.3	1.8	0.0	2	0
Feb	0.1	0.9	0.0	1	0
Mar	0.1	0.5	0.0	1	0
Apr	0.4	1.8	0.0	4	3
May	4.0	13.0	2.4	13	6
Jun	5.8	10.6	2.2	16	12
Jul	4.7	14.5	2.6	14	16
Aug	4.9	8.8	2.1	14	16
Sep	3.4	8.4	2.6	11	12
Oct	7.7	12.6	2.4	20	9
Nov	6.0	15.6	3.1	19	6
Dec	3.3	6.8	0.8	12	3
Annual Total	40.7	95.3	18.2	127	83

*Length of Record: 4 years (to 1947).

TABLE IX. RELATIVE HUMIDITY (%)

RIO HATO MILITARY RESERVATION AIRFIELD, R. P.*

Month	Mean	0600 hours	1400 hours	2200 hours
Jan	74	84	58	80
Feb	71	80	55	77
Mar	71	81	58	75
Apr	74	83	64	76
May	83	88	74	86
Jun	87	92	78	90
Jul	85	91	77	88
Aug	86	90	78	89
Sep	87	94	77	91
Oct	89	94	79	93
Nov	87	93	76	91
Dec	83	91	71	88
Year	85	88	70	85

*Length of Record: 4 years (to 1947)

TABLE X. WIND AND SKY DATA

RIO HATO MILITARY RESERVATION AIRFIELD, R. P.*

Month	Mean Wind Speed	Prevailing Wind Direction	Mean Cloud Cover (tenths)	Days With Fog
Jan	9	NNW	4.2	0
Feb	9	N	3.8	1
Mar	10	N	4.2	0
Apr	9	N	5.4	0
May	7	NW	6.9	1
Jun	6	NW	7.6	1
Jul	7	NW	7.6	0
Aug.	7	NW	7.5	1
Sep	6	NW	7.6	1
Oct	7	NW	7.7	2
Nov	7	NW	7.0	2
Dec	8	NW	5.8	1
Year	8	NW	6.3	10

*Length of Record: 7 years (to 1949)

APPENDIX C

PHOTOGRAPHS*

*See "List of Figures" at beginning of report

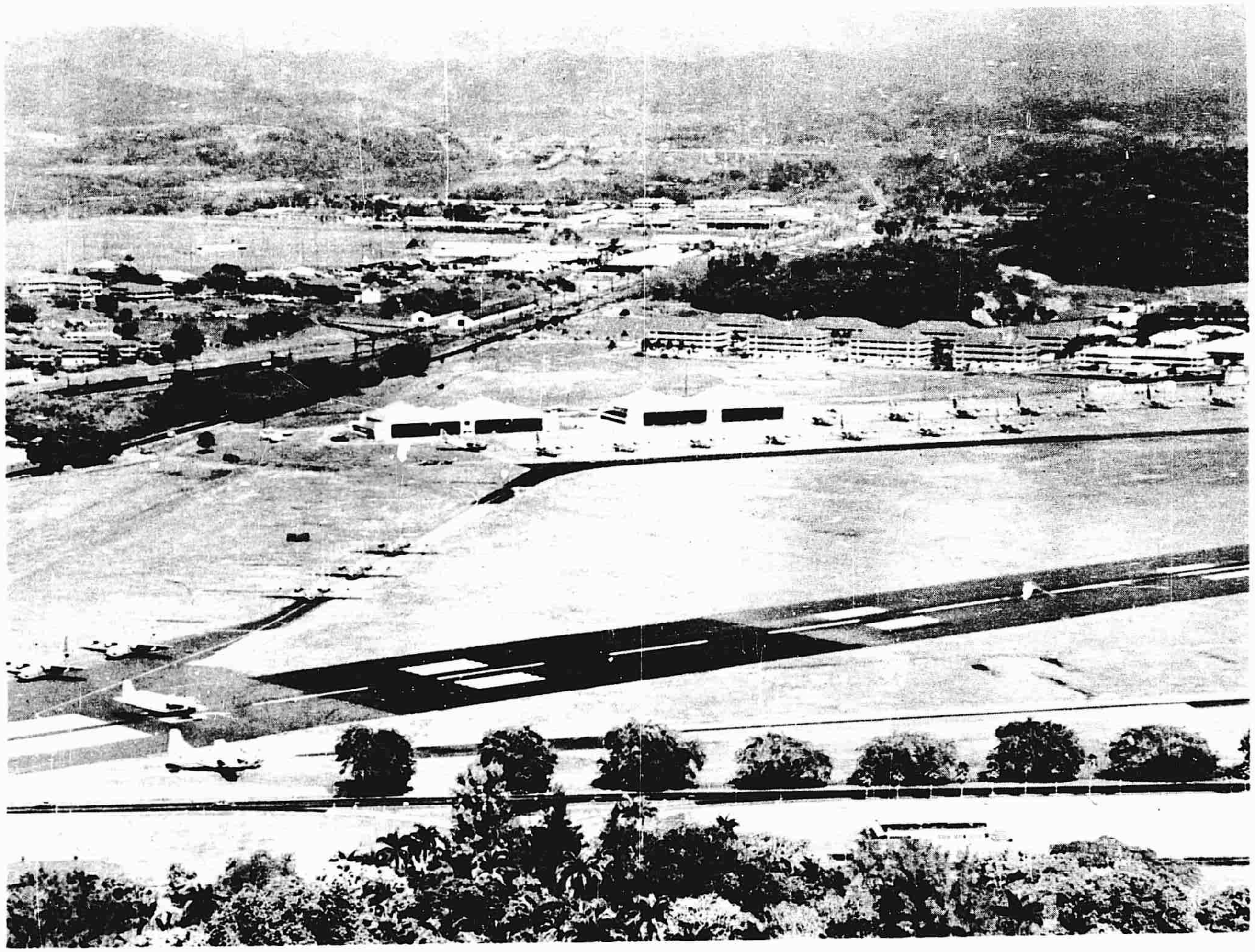


Figure 31. Albrook Air Force Base. View from Ancon Hill looking in a northeast direction. Notice the dense vegetation in the foreground and the numerous hills in the background.

Figure 32. Fort Kobbe. The dense vegetation north of Fort Kobbe provides an excellent location for testing or training in tropical forest environments.

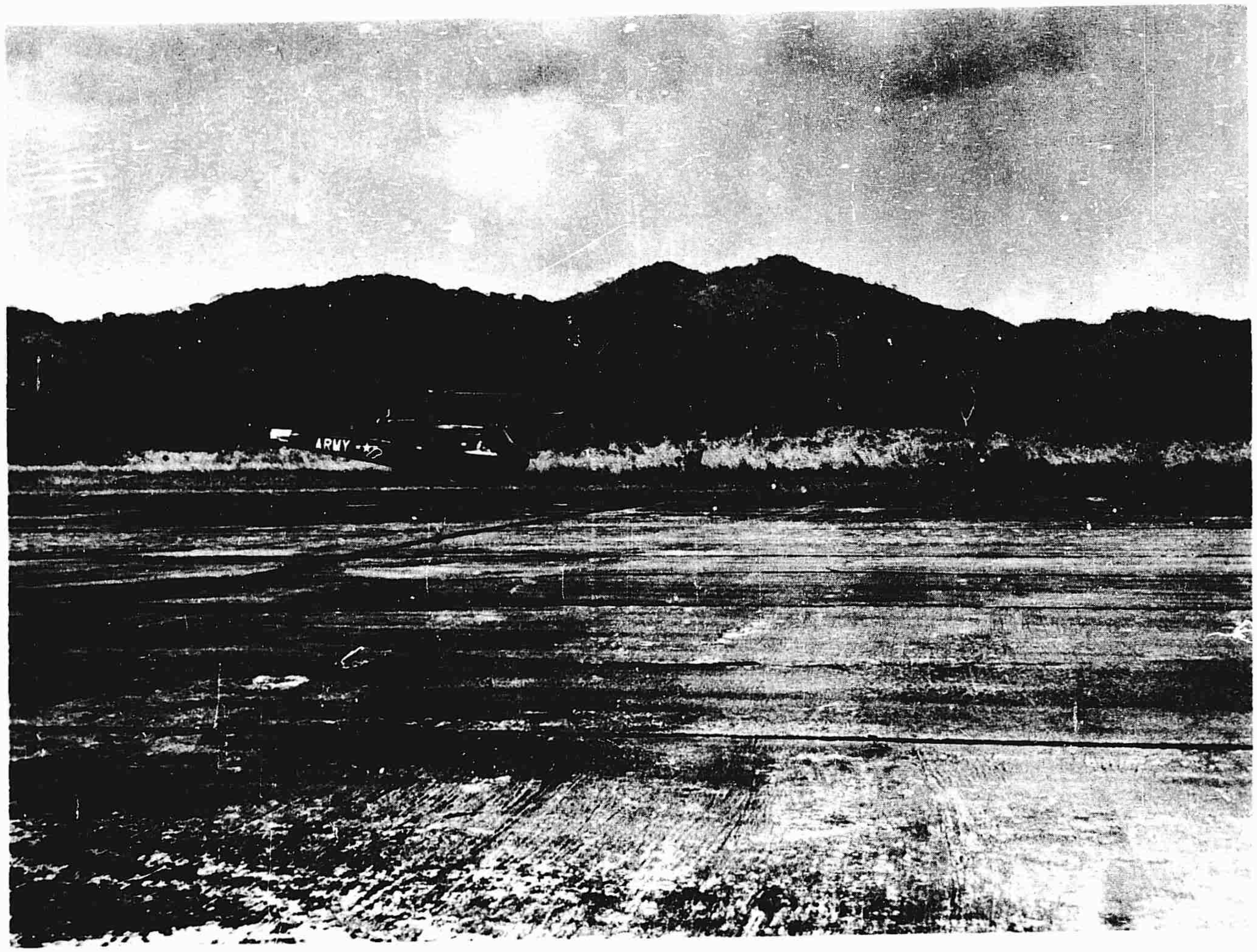


Figure 33. Howard Air Force Base. View from the main runway looking in a westerly direction. The steep hills in the background are covered with a dense deciduous forest, much of which has a closed canopy.

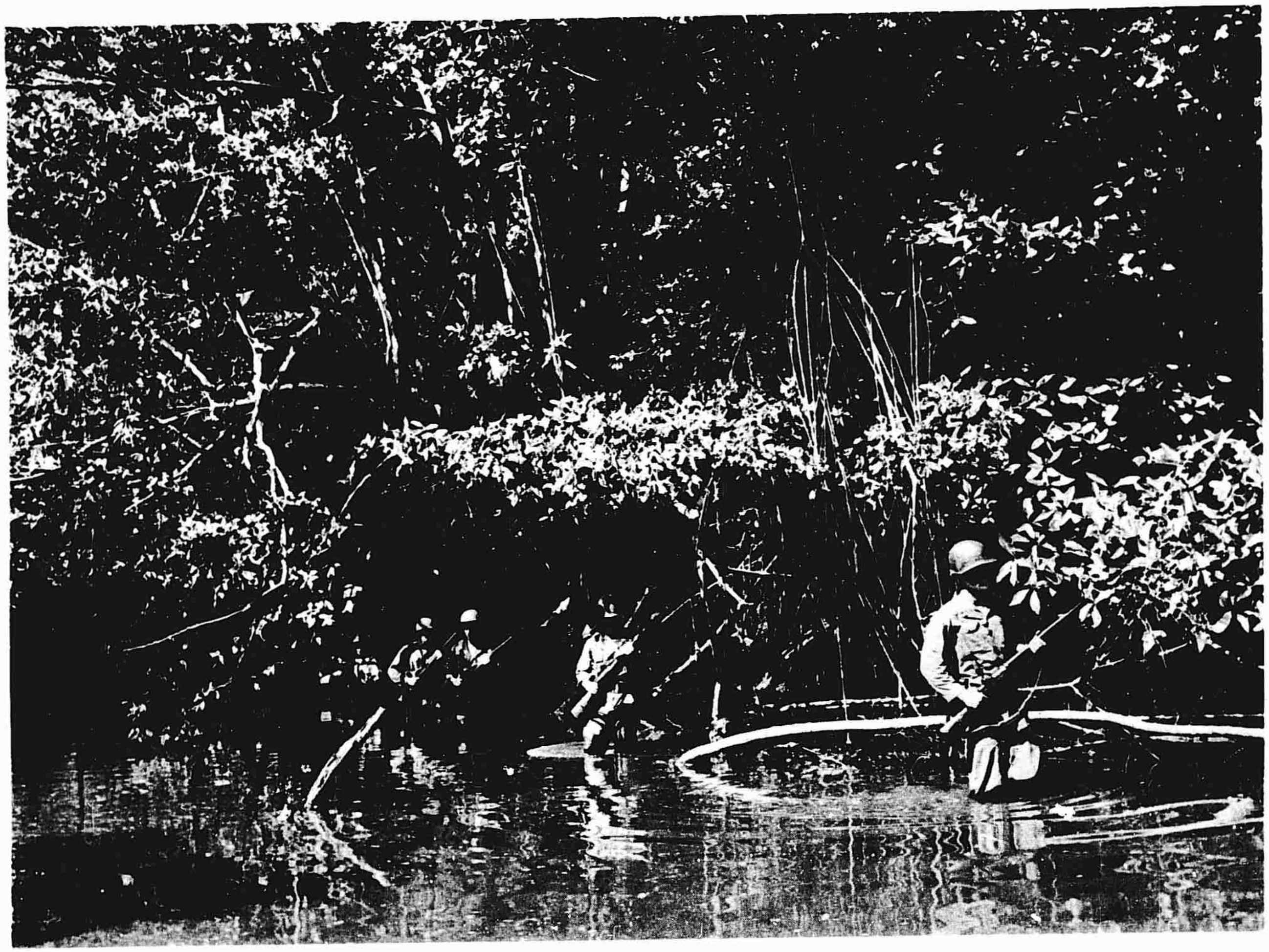


Figure 34. Mangrove Swamp. This swamp is located in Fort Kobbe near the Bay of Panama. The stilt roots of the mangrove present an almost impenetrable barrier to movement.

Figure 35. Cut-over forest. This forest near Fort Kobbe was cleared of all vegetation approximately 25 years ago. The heavy undergrowth will gradually be shaded out as the canopy becomes better developed.

Figure 36. Open lowland. This low vegetation is characteristic of the open lowlands that are only occasionally cleared. View from Fort Grant Military Reservation, Culebra Island, looking south to Isla Tobogvilla.

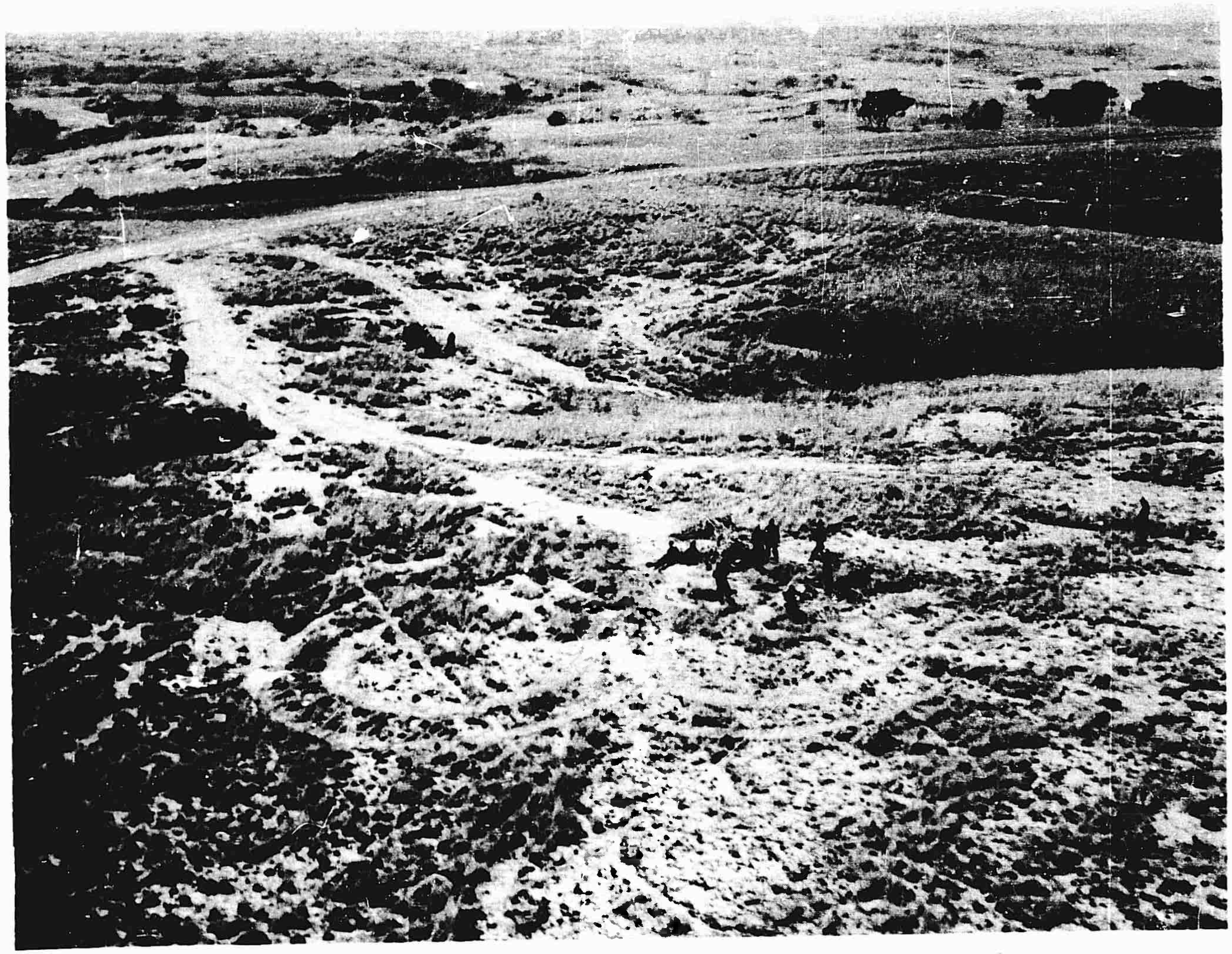


Figure 37. Rio Hato Military Reservation. Notice the nearly-level horizon, and the gently undulating character of the landscape. This view is toward the southwest, and shows the nature of the vegetation during the early part of the dry season.

Figure 38. Dusty road at Rio Hato. This road-side vegetation is not common. Most of the roads are located in the middle of a corridor, and most of the trees are located at the edges of corridors or in valleys.

Figure 39. Edge of a corridor at Rio Hato. In the background the relatively deep canyon of a small stream is lined with stunted vegetation. The nearly-level land in the foreground is typical of the corridors in the Rio Hato area.

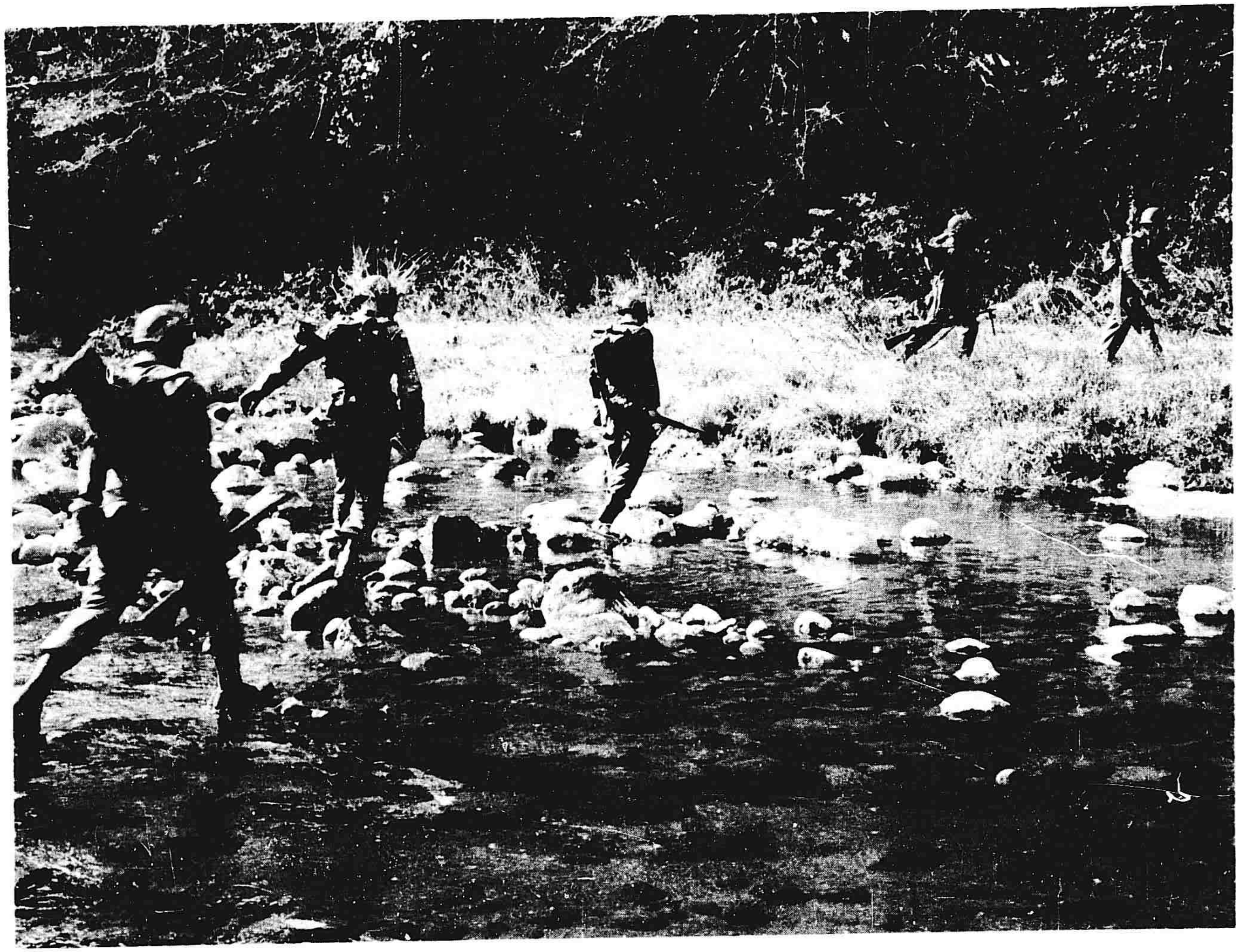


Figure 40. Crossing a stream at Rio Hato. The sandy boulder-strewn beds of the streams make quebrado crossing easy during the dry season. The steep rock sides of the quebrado are made more difficult to climb because of the thick thorny vegetation.

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